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FABRICATION AND TESTING OF TWO (2) NON-SPIN
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FINAL REPORT

on

THE DESIGN, DEVELOPMENT, FABRICATION AND TESTING

of

TWO (2) NON-SPIN PLATFORMS, (NSP)

CONTRACT NO. NAS8-30528

Prepared for:

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SUMMARY

In summary, the Non-Spin Platform is a means for achieving the very low acceleration requirements for cost effective Space Processing Experiments on Research Rocket Flights. Since it is mandatory to hold the cost of each flight to a minimum, these platforms have a low initial cost, are re-usable and have extremely low refurbishment costs. In order to attain this goal, commercially available components were used and only the necessary quality control standard were imposed.

The following portions of this report include a detailed system description; describes the very few design problems encountered; defines the operational procedures (both pre-flight and post-flight); and describes the maintenance requirements.

1. SYSTEM DESCRIPTION

1.1 Structure

The Non-Spin Platform supports the payload on experiment mounting plates which do not rotate with the spinning rocket, and connects it mechanically to the ring-frame of the rocket payload section.

The basic configuration of the structural sub-system is shown in Figure 1 and 2. The bearing hub assembly attaches to the rocket extension assembly, and carries a pair of preloaded angular contact bearings. The central shaft of the non-spinning platform is carried by the inner races of these bearings. A large diameter D.C. torque motor surrounds the shaft so as to exert torque between the non-spinning shaft and the rocket extension connected support.

A forward mounting plate is attached to one end of the shaft and an aft mounting plate is attached to the other end. On the internal side of each plate are mounted the servo transducers, electronics for driving the motor, batteries and other necessary components. The external side of each plate serves as a mounting surface for the support module and the measurement modules, which are not part of the NSP.

Two (2) sets of slip rings, one 50 segment set for ground control functions and one 8 segment set for external power, provide electrical connections from the missile to the non-spin platform.

NON-SPIN PLATFORM

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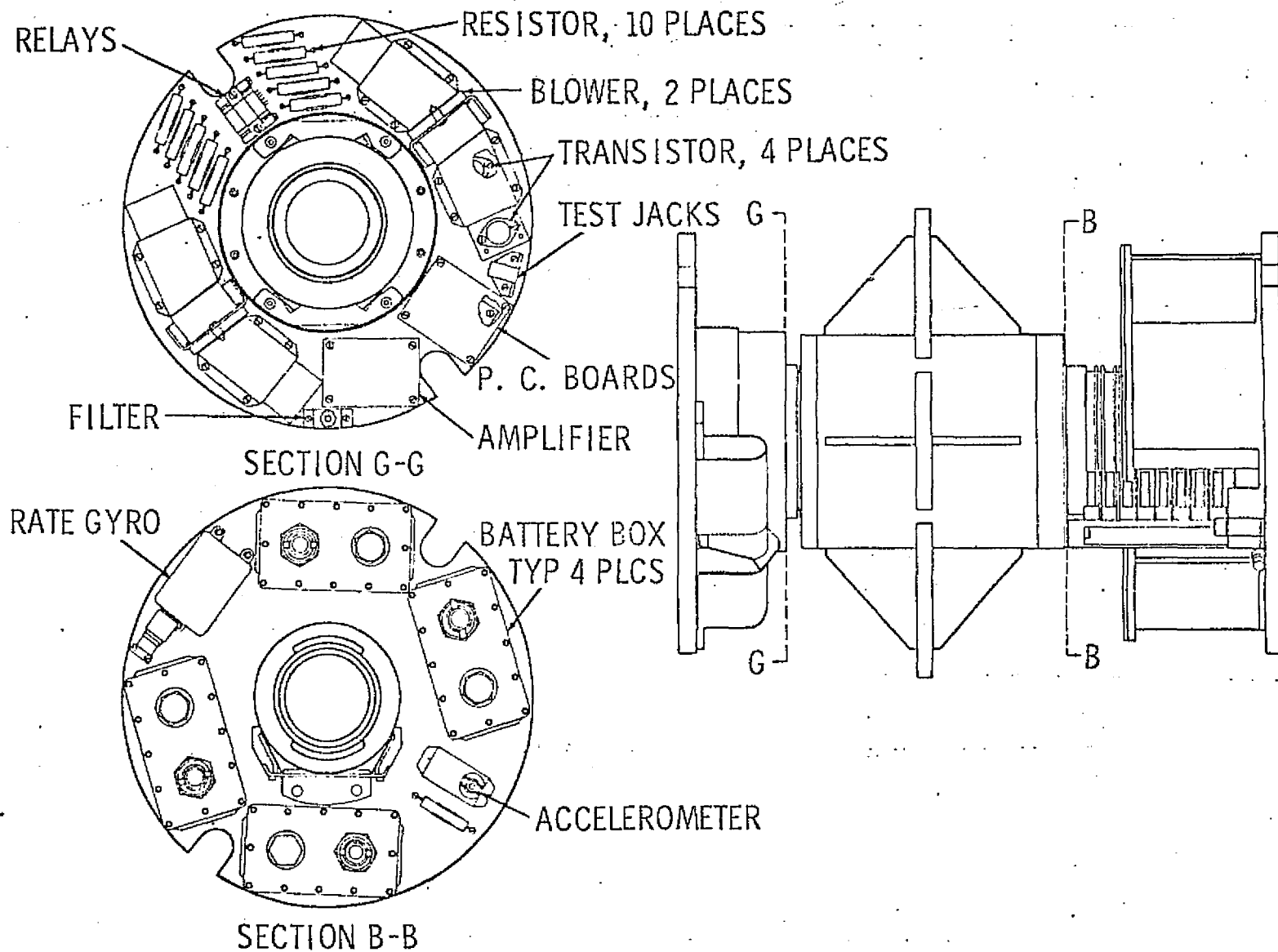


FIG 1

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NON-SPIN PLATFORM

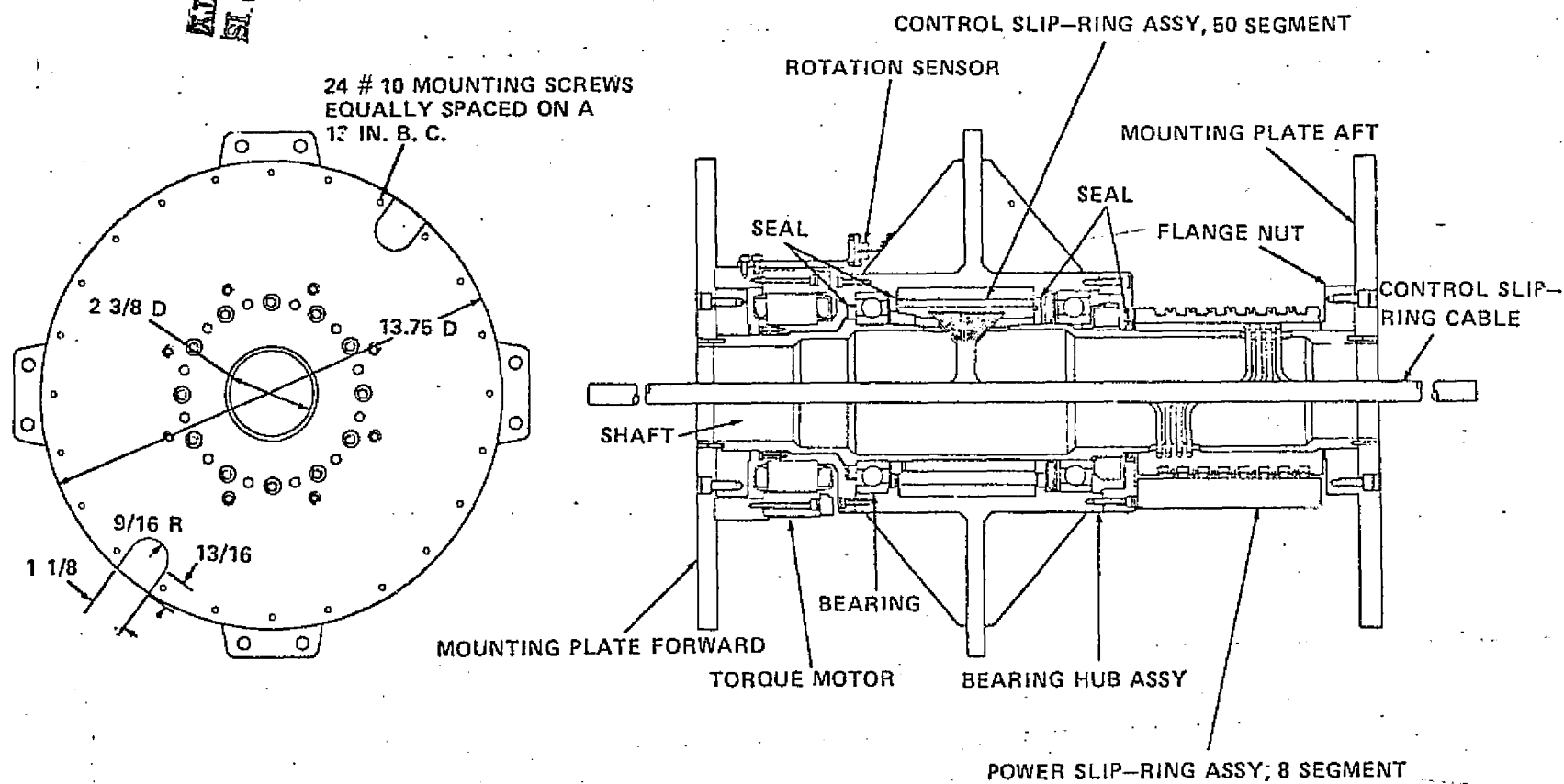


FIG 2

All the main structural elements, except for the shaft, are made from aluminum alloy; both in the interest of weight saving and low fabrication cost. The shaft is made of 17-4PH steel due to strength considerations.

The bearing lubricant is KG-80 oil.

1.2 Rotation Sensing and Control System

A block diagram of the sensing and control system is shown in Figure 3. The system is designed to maintain the rotational velocity and acceleration below the following limits:

During upward leg of trajectory (maximum rocket spin rate 276 RPM (29 rad/sec):

$$\omega_{\max} = 5 \text{ RPM} = .53 \text{ rad/sec}$$

$$\alpha_{\max} = 2 \text{ RPM/sec} = .21 \text{ rad/sec}^2.$$

During coast phase of trajectory:

$$\omega_{\max} = 1 \text{ RPM} = .105 \text{ rad/sec}$$

$$\alpha_{\max} = .25 \text{ RPM/sec} = .026 \text{ rad/sec}^2.$$

The sensing and control system meets or exceeds these requirements. A servo analysis has been performed. A block diagram of the servo loop, in Laplace notation, is given in Figure 3, assuming the ideal transfer functions for the components.

The symbols used are defined as follows:

J = platform moment of inertia, kg m^2

T_D = platform disturbance torque, Nm

θ = platform angle

ω = platform angular velocity

α = platform angular acceleration

K_1 = Servo amplifier gain, A/V

K_2 = Torquer gain, Nm/A

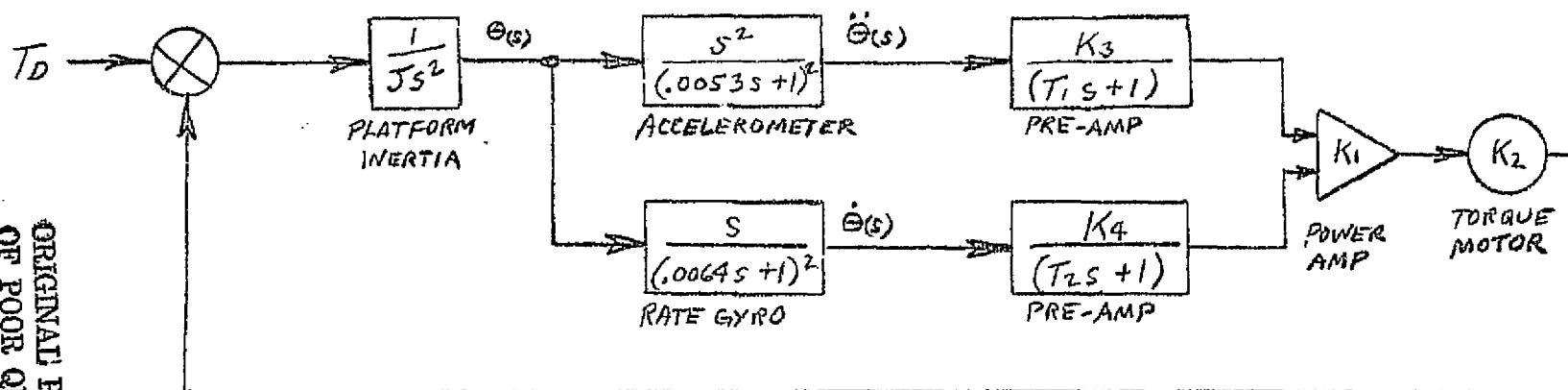
K_3 = Angular Accelerometer and Pre-amp Gain,
 V/rad/sec^2

K_4 = Rate Gyro and Pre-amp Gain, V/rad/sec

T_1 = Accelerometer Pre-amp roll-off Time Constant

T_2 = Rate Gyro Pre-amp roll-off Time Constant

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$$\frac{\dot{\Theta}(s)}{T_D} = \frac{(T_1 s + 1)(T_2 s + 1)}{J T_1 T_2 \left[s^3 + \left(\frac{1}{T_2} + \frac{1}{T_1} + \frac{K_1 K_2 K_3}{J T_1} \right) s^2 + \left(\frac{1}{T_1 T_2} + \frac{K_1 K_2 K_3}{J T_1 T_2} + \frac{K_1 K_2 K_4}{J T_2} \right) s + \frac{K_1 K_2 K_4}{J T_1 T_2} \right]}$$

$$\frac{\ddot{\Theta}(s)}{T_D} = \frac{\dot{\Theta}(s)}{T_D} s$$

$$K_1 = 2 \text{ A/V}, K_2 = 0.68 \text{ Nm/A}, K_3 = 36 \text{ V/rad/sec}^2, K_4 = 50 \text{ V/rad/sec}$$

RESPONSE OF THE UNLOADED PLATFORM TO A TORQUE STEP OF 1 Nm:

$$T_1 = 3.18 \text{ sec.}, T_2 = 0.024 \text{ sec.}$$

$$\dot{\Theta}(s) = \frac{(s + 3.14)(s + 41.7)}{.25(s + .255)[(s + 51.67)^2 + 13,885]}$$

$$\dot{\Theta}(t) = 0.147 - .00058 e^{-.255t} - .0078 e^{-51.7t} \cos(118t - 62^\circ)$$

NOTE: THE FREQUENCY RESPONSE CHARACTERISTICS OF THE SENSORS ARE NOT INCLUDED, SINCE THE TIME CONSTANTS, T_1 AND T_2 , PREDOMINATE.

Fig. 3
NON-SPIN PLATFORM
SERVO LOOP BLOCK DIAGRAM

s = Laplace operator

The response of the platform to disturbance torques, such as those transmitted through the support bearings, torquer brush friction, coaxial rotary joint, etc., is shown in Laplace notation, on Figure 3.

For simplicity, the frequency response characteristics of the sensors are ignored. This is justified, since the critically dampened resonances of both the accelerometer and the rate gyro occur outside the band width of the servo system. The system band width is determined by the time constants, T_1 and T_2 .

The values of T_1 and T_2 required to stabilize the unloaded platform ($J = 0.25 \text{ kg m}^2$) are:

$$\begin{aligned} T_1 &= 3.18 \\ T_2 &= 0.024 \end{aligned}$$

In order to optimize system response, these values should be changed where the experiment packages are mounted upon the platform. For an assumed value of $J = 2.5 \text{ kg m}^2$, T_1 may be reduced by a factor of 10, to 0.318 seconds. This may be accomplished by reducing the feedback capacitor on the accelerometer pre-amp from 175 microfarads to 17.5 microfarads.

With the larger value of J , time constant T_2 is not necessary for loop stability. However, it is recommended that a roll-off capacitor be kept for noise reduction. The delivered value of 0.47 microfarads could be reduced to 0.22, giving a roll-off frequency of approximately 15 hertz.

2.0 DESIGN PROBLEMS

2.1 Optimum Structural Design

In approaching the problem of an optimum structural design, two (2) basic requirements were presented. It was essential, due to the platform application on a space vehicle, that the weight be kept to a very minimum. Also, as a goal, and in keeping with the cost effectiveness imposed by this program, it was necessary that the platform survive only the reentry and recovery gravitational loads. The shock load imposed upon landing was not used.

A high strength aluminum alloy (7075-T6) was originally proposed for the shaft, bearing retaining nut, and the two (2) plates (forward and aft). Aluminum alloy 2024-T851 was selected for the legs and mounting hub.

Analysis showed that alloy 7075-T6 was inadequate to meet the strength requirements of the shaft. A steel alloy 17-4PH, H1025 was substituted. Appendix I presents an analysis performed by NASA to define the optimum shaft design. When manufacturing costs were considered, the optimum shaft design resulted in one shown on Drawing 95M16001, Shaft, Non-Spin Platform.

An analysis of the Bearing Retaining Nut is presented in Appendix II and shows a more than adequate safety factor.

An analysis of the bending moments, stress diagram, and stress in both the upper and lower plates can be found in Appendix III.

These calculations are based on the fact that the Measurement Module (M.M.) and Support Module (S.M.) are rigidly attached to their respective NSP plates and the combination act as a solid plate of the thickness equal to the sum of the thickness of the two plates (Reference: "Guide to Design Criteria for Bolted and Riveted Joints", Fisher and Struik, 1974, Chapter 5)

Appendices IV, V and VI and Appendix IX are included at the Government's request. The inclusion of these Appendices is not to imply full concurrence by Astro-Space Laboratories, Inc., but are included for information only and in order to comply with Government instructions. In way of comment, we wish to point out that in these appendices, the conclusions are based on the maximum payload being 393 pounds, the Factor of Safety required is 1.5 and the "G" load equals 25. It is suggested that if the maximum payload of 300 pounds be used, the realistic "G" load of Appendix VI be used and the Factor of Safety as defined in MSFC-HDBK-505 be applied, much more favorable results will be obtained and a more realistic evaluation of the NSP capability be obtained.

Appendix VII presents an analysis of the Mounting legs (Platform to missile interface). Again, a more than adequate design is presented. This design represents a design initiated as a weight savings move. An analysis of the original design showed that the design was too conservative to be consistent with the program weight savings philosophy.

2.2 Battery Voltage

Limited cell tests indicated that the cell voltage was below that specified by the manufacturer. In anticipation of the need to increase the battery voltage, the design of the box was such that up to six cells can be put in each box, if required. (See Appendix VI)

3.0 Waivers and Out of Specification Conditions

See Paragraph 2.1

4. OPERATING PROCEDURES

4.1 Interfaces

Interface connections between the Non-Spin Platform and ground control equipment are provided through slip-rings. These connections allow the operation of the platform from ground power during pre-launch operations, as well as during testing. The slip-ring numbers and their interface functions are listed below.

Slip-Ring Number	Function
38	Blower power, 115 Volts, 400 Hertz
39	Blower power return
40	Telemetry ground power, + 28 VDC
41	Rate Gyro ground power, + 28 VDC
42	Timer STOP ground control, + 28 VDC pulse
43	Timer START ground control, + 28 VDC pulse
44	Telemetry GROUND POWER switch, + 28 VDC pulse
45	Telemetry INTERNAL POWER switch, + 28 VDC pulse
46	Rate Gyro GROUND POWER switch, + 28 VDC pulse
47	Rate Gyro INTERNAL POWER switch, + 28 VDC pulse
48	Servo Amplifier GROUND POWER switch, + 28 VDC pulse
49	Servo Amplifier INTERNAL POWER switch, + 28 VDC pulse

Slip-Ring Number	Function
50	Rate test, 28 VDC
7	Servo Amplifier ground power, + 28 VDC
8	Ground Power Return

Note: Rings 38 through 50 are on the signal ring block and 7 and 8 are on the power ring block.

4.2 Checkout and Control Console Description

The Checkout and Control Console provides switches for control of the power applied to the platform, meters for monitoring the 28 VDC voltage and current, and momentary-contact switches for control of the GROUND POWER - INTERNAL POWER relay functions.

In all but the "rocket spin-simulation" test, the control console connections to the platform are to the umbilical cable, and hence, through the slip rings. In the "spin-simulation" test, the rocket-fixed side of the slip-rings are spun with the test fixture and umbilical cable. In this case, it is more practical to by-pass the slip-rings, and make temporary connections from the control console directly to the non-spin platform.

The schematic diagram for the control console panel is included as Figure 4.

4.3 Checkout and Control Console Operation

The Non-Spin Platform may be operated, and certain tests performed, using the console for controlling the platform functions. In addition to the slip-ring connections listed in 4.1, provisions are made for connecting the platform test points to jacks on the front panel of the console. These jacks then provide convenient access to these test points.

After the platform to console cabling has been completed, the following power must be supplied to the designated terminals of the console:

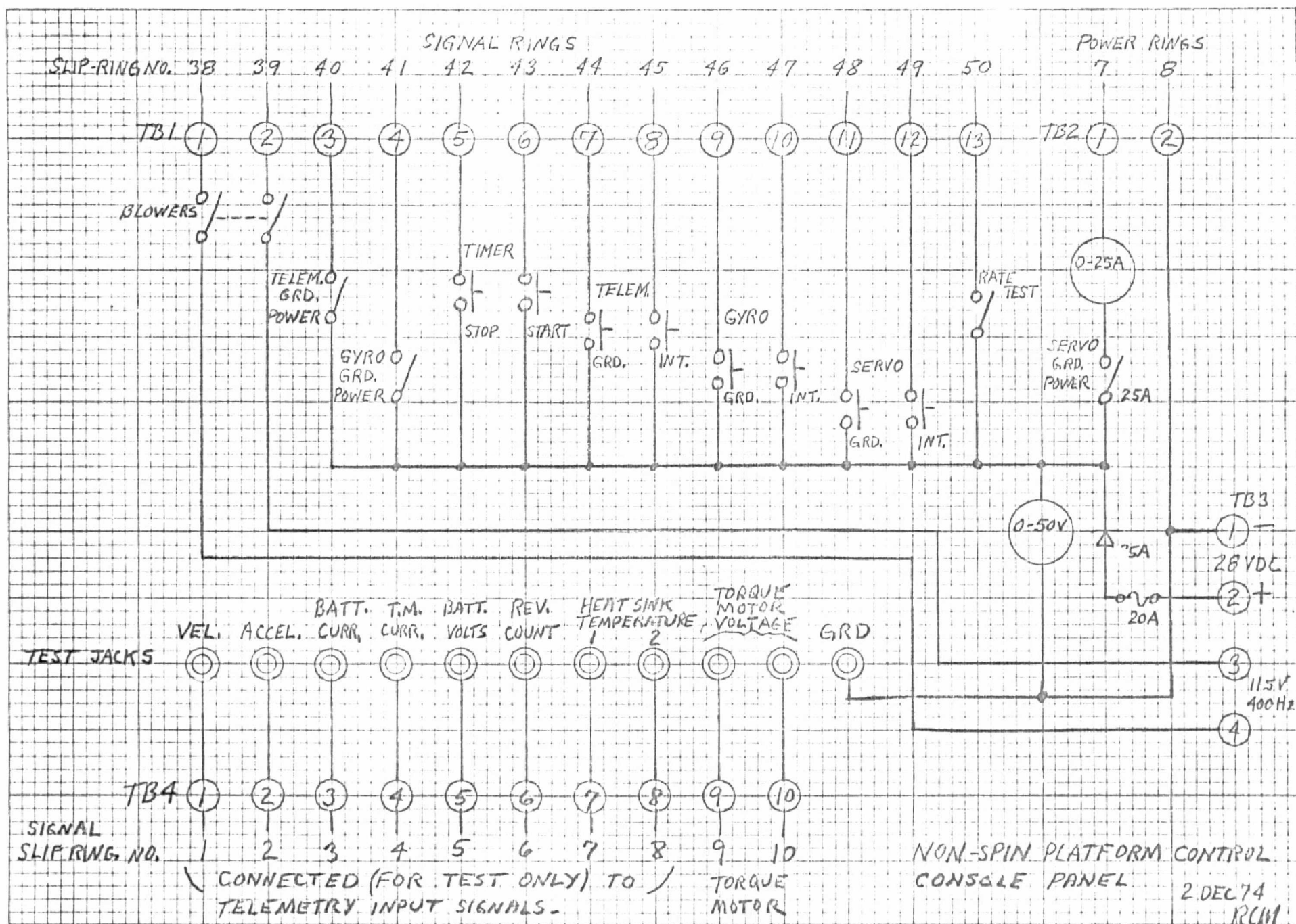


FIG. 4

115V, 400 Hz blower power
28 VDC, 25 amp capacity

To put the platform into operation:

1. Place all switches on the control console in the OFF position. The console panel meter should read approximately 28VDC.
2. Operate all the GROUND-INTERNAL momentary contact switches in the GROUND position. This will latch all power transfer relays in the platform in the GROUND POWER position.
3. Turn ON the blower switch.
4. Turn ON the gyro switch. Wait one (1) minute for the gyro to come up to speed.
5. Turn ON the servo switch. The platform will now be stabilized.

To shut down the platform, follow the reverse sequence.

WARNING: It is important that the Gyro Switch be ON, and the Gyro up to speed, before the Servo Switch is turned ON. Also, the Servo Switch must be turned OFF before the Gyro is turned OFF.

4.3.1 Servo Amplifier and Torque Motor Tests

Proper operation of the servo amplifier and torque motor can be demonstrated by a simple closed-loop test, if the rate gyro is functioning properly. The test consists of applying a known torque to the stabilized axis of the platform, and measuring:

- 1) the ensuing rate
- 2) the torque motor voltage
- 3) the torque motor current

This test should be performed for both CW and CCW torques.

The nominal values of the servo systems parameters which can be determined from the above test are as follows:

Loop gain: 68 Nm per rad/sec

Torque constant: 0.68 Nm per ampere

The servo amplifier is capable of putting out some 20 to 25 amperes, and producing 14 to 17 newton-meters of torque. The brush rating of the torque motor for continuous operation is 15 amperes, or 10 newton-meters torque.

4.3.2 Drift Tests

Gyro drift will result in a constant output current from the servo amplifier. This current may or may not cause an actual drift of the platform, depending upon whether the current is sufficient to overcome the frictional torque about the platform axis. This current can be minimized, or set to zero, by adjusting the trim pot, R8, on the rate gyro pre-amplifier.

4.3.3 Rate Test

Provision has been made for applying an error signal in the rate loop, producing a fixed platform turning rate. This signal is applied by energizing relay K5, through slip ring 50. A switch to operate this relay appears on the control console.

This rate signal may be used during pre-launch testing to ensure that the platform servo loop is operational. The slow rotation of the platform (approximately 30°/sec) will be indicated by:

- 1) an approximately full scale output from the telemetered rate signal, and 2) output pulses from the Revolution Counter (approximately 20 pulses per minute).

4.3.4 Power Transfer

Power Transfer, that is, transfer of the platform power supply from ground power to internal batteries, is accomplished in steps by operating the transfer relays on the platform. A suggested operating sequence is as follows:

1. Operate the Telemetry switch to INTERNAL POWER. This will latch K3 to supply power to the telemetry system from the non-spin platform battery. It will also allow the battery voltage to be read by means of the telemetered signal.

2. Operate the Servo switch to INTERNAL POWER.

3. Operate the Gyro switch to INTERNAL POWER.

After these operations have been performed, ground power may be removed from the platform.

4.3.5 Rocket Spin Simulation Test

The rocket spin simulation test has been performed upon the Non-Spin Platform to prove the system concept and performance. In this test, the platform was mounted on a spin table. With the platform operating from a special umbilical cable (which by-passed the slip rings) the spin table was rotated up to 200 RPM. The platform rotation during these tests was measured as being approximately 0.5 RPM, or ten (10) times smaller than the maximum allowable value of 5 RPM.

From these results, it was concluded that the system would operate within the 5 RPM limit during rocket acceleration.

4.3.6 Revolution Counter

The Revolution Counter produces an output of 4 pulses per revolution of relative motion between the non-spin platform and the rocket. It consists of a G.E. H13A2 interrupter module mounted on the stabilized portion of the non-spin platform, with four (4) interrupting vanes attached to the mounting legs of the platform hub. During relative rotation, the vanes pass through the module, interrupt the light beam, and produce an output pulse.

The output pulses may be checked by means of an oscilloscope hooked to the module output. Manual rotation of the platform to cause one of the vanes to pass through the module will produce an output pulse which can be observed. The normal output of the module is between 4.5 and 5 VDC positive with respect to ground. When a vane interrupts the light beam, the output drops to between 0.5 and 1 VDC.

4.4 MAINTENANCE (PRE-FLIGHT AND POST-FLIGHT)

4.4.1 General Information

The Non-Spin Platform is essentially maintenance free; however, in order to minimize maintenance, the NSP should be covered or otherwise protected against the entrance of dust or foreign particles, particularly metallic, during transportation, storage or other periods of inactivity. For long periods of storage, the NSP should be stored in a sealed container along with desiccant suitable for protection against excess humidity.

Unanticipated maintenance will be required should inadvertent electrical shorting cause burn-out of any component. In this case, the component should be replaced. Whereas there are no spares requirement under this contract, most items used are standard and are readily available, i.e., resistors, capacitors, semi-conductor devices, etc.

The following paragraphs define both pre-flight and post-flight anticipated maintenance on detail parts and do not include unanticipated maintenance as described in previous paragraph.

4.4.2 Batteries

Fresh batteries should be installed prior to each flight. Battery storage, activation and maintenance are described in Appendix V, Service and Operating Instructions for the Yardney Silvercell Battery.

4.4.3 Rate Gyro

The Rate Gyro characteristics are described in Table 1.

No maintenance is anticipated; however, should the Gyro fail to perform as specified, it should be returned via EC-22 to MSFC's Electronics and Control Laboratory for analysis.

4.4.4 Angular Accelerometer

The Angular Accelerometer (Model ASBC-50) characteristics are described in a separate booklet, "Linear and Angular Servo Accelerometers", produced by the manufacturer, Schaevitz Engineering, Pennsauken, New Jersey. A copy of this booklet is supplied with each unit.

No maintenance is anticipated; however, should the accelerometer fail to perform as specified, it should be returned via to EC-22 MSFC's Electronics & Control Laboratory for analysis.

4.4.5 Power Pre-Amplifier

An Inland Motor Corporation of Virginia, Model EM-1802 is used as Power Pre-Amplifier. This unit is described in Appendix VI.

No maintenance is anticipated; however, should the amplifier fail to perform as specified, it should be returned via EC-22 to MSFC's Electronics & Control Laboratory for analysis.

Single Axis DC/DC Standard
Rate Sensor Assembly
Part Number 79131-350
MEASURED CHARACTERISTICS

Weight	1.0 lb. (max.)
Outline Dimensions	Dwg. No. 68215
Power Input	7 w. (max.) at 31 vdc
Input Voltage Limits	28 \pm 3 vdc
Full-Scale Output	\pm 2.5 vdc
Output Impedance	200 max.
Output Load Resistance	10K min. load
Ripple	25 mv. peak-to-peak (max.) @ +2.5 volts DC
Zero Rate Setting	\pm 1 1/2% FS
Input Range*	50°/sec
Maximum Input Rate*	1000°/sec
Output Voltage Overrange Limits	\pm 15 volts DC
Output Stability, Input Voltage Variations	1/2% FS
Repeatability	1% FS
Threshold*	0.05°/sec
Resolution*	0.05°/sec
Hysteresis*	0.1°/sec
Operating Temperature	0°F to +160°F
Temperature Sensitivity	Zero Rate Output 1% FS/100°F, max. Scale Factor 3%/100°F, max.
Warm-up Time	10 minutes
Gyro Spin Motor Acceleration Time	30 sec. (max.)
Gyro Gimbal Deflection Angle	\pm 2° typical
Acceleration Sensitivity	
Linear*	0.1°/sec./g
Angular	0.08°/sec./rad./sec. ²
Linearity	1/2% FS, from 0 to half scale 2% FS, half scale to full scale
Service Life	1000 hr. (min.) or 1 year
Insulation Resistance	10 megohms minimum at 50 vdc
Damping Ratio*	0.5 to 0.9
Natural Frequency*	50 Hz
Environments	
Shock	250 g peak sawtooth, 5 msec.
Vibration	0.1 g ² /Hz, 20-2000 Hz
Storage Temperature	-65°F to +200°F
Radio Frequency Interference	MIL-I-8161D

* Parameters that are a function of the rate sensor used.

NOTES:

1. The output signal is isolated from the input common.
2. The output signal is protected from any damage occurring as a result of inadvertent shorting.
3. The standard single-axis dc/dc configuration is also available with control outputs of \pm 5 vdc.
4. There are several models of the Standard GR-G5 Rate Gyro to choose from, accommodating full-scale rate inputs from 20 to 1000°/sec. Variable limits for natural frequency, acceleration sensitivity, threshold and resolution as a function of input rate are shown in the G5 parameter table.

4.4.6 Power Amplifier

The Power Amplifier consists mainly of all solid state devices, conservatively rated, heat sink mounted and applied in a reliable circuit designed to require no maintenance during either the pre-flight or post-flight periods.

4.4.7 Torque Motor

The Torque Motor is an Inland Motor Company, Model T-5745, wound to the characteristics shown in Table 2. As the Torque Motor is rigidly mounted as an integral part of the NSP and is essentially inaccessible, no routine maintenance is scheduled or expected. The cautions relative to storage (Paragraph 4.4.1) should be re-emphasized.

In the rare instance of maintenance requirement or if the motor be removed for any reason, it is recommended that: the brushes be examined for wear and replaced, if necessary; the commutator be inspected and cleaned if necessary; and remagnetization be considered. The commutator and brushes can be inspected without motor removal.

4.4.8 Bearings

The Bearings are Fafnir Bearing Company, P/N 3MM917JW1. The bearings have been pre-lubricated with Kendall KG-80 oil per Fafnir recommendations (baked 6 hours at 150°F and vacuum impregnated) and are sealed on both sides to preclude the entrance of foreign material and to entrap the lubricant.

In order to maintain the integrity of the bearing lubrication, the NSP should be rotated (by hand or otherwise) a minimum of five (5) revolutions once a week.

Since it is impossible to accurately determine the effect of ground impact on the bearings (and ultimately, the NSP performance), replacement of the bearings will have to be determined on a flight by flight basis.

4.4.9 Slip Rings

The Power Slip Rings and Brush Block, Electro-Tec Corporation P/N 43705-3 and -4, will require little or no maintenance because the high brush pressure and relative high currents used.

The Signal Slip Rings and Brush Block, Electro-Tec Corporation P/N 43705-1 and -2, will require little or no maintenance because they are enclosed in a sealed-off area between the two bearings.

Should the NSP be disassembled for any reason, the slip ring assemblies should be inspected and cleaned, if necessary. The "power slip rings" can be inspected and cleaned without disassembly.

SECTION 2 — TORQUE MOTORS

DC TORQUE MOTORS

MOTOR CONSTANTS	MODEL NUMBER				
	T-5406	*T-5503	T-5730	T-5745	T-5751
Peak torque (T_P), lb-ft	2	.84	7	14	10
Electrical time constant (τ_E), milli-sec	1.5	0.77	2.7	5.3	2.9
Power input, stalled, at peak torque (P_P), watts	52	81	260	357	457
Infinite impedance source (F_I), lb-ft/rad/sec	.003	.0006	.003	0.01	.002
Motor friction torque (T_f), lb-ft	0.12	0.028	0.07	0.15	0.20
Ripple torque, average to peak (T_R), %	6	6	4	4	4
Ultimate temperature rise per watt (TPR), °C	2	3.2	2	1.3	0.8
Max permissible winding temperature, °C	105	105	105	155	155
Rotor moment of inertia (J_M), lb-ft-sec ²	.0015	.00015	.005	0.008	.0072
No load speed (ω_{NL}), rad/sec	19	72	(27)	10.75	32
Motor weight, lb	3	1.18	7.25	15	14

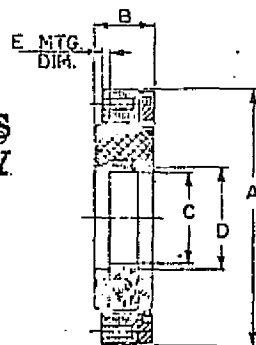
*Inside out design

WINDING CONSTANTS

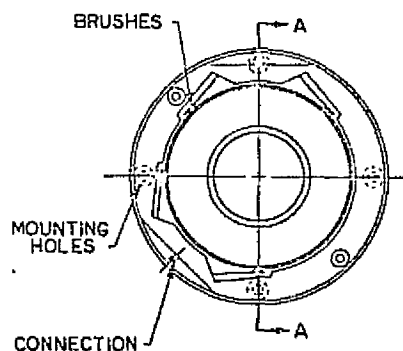
DC resistance (25°C), (R_M), ohms	13	4.45	3.5	0.5	1.20
Volts at peak torque (V_P), volts	26	19.1	30.6	14.1	23.4
Amps at peak torque (I_P), amps	2	4.50	8.76	28.2	19.5
Torque sensitivity (K_T), lb.-ft. amp	1	0.193	0.80	0.5	0.54
Back EMF (K_M), volts/rad/sec	1.36	0.26	1.09	0.68	0.73
Inductance (L_M), milli-hys.	20	3.3	10	2.4	34

MECHANICAL DATA

A. Outside diameter	6.1250	6.500	7.200	7.200	8.19
	6.1245	6.498	7.198	7.198	
B. Width	1.168	0.625	1.625	2.375	3.758
C. Inside diameter	4.5000	4.720	3.950	3.950	1.750
	4.5005	4.718	3.951	3.951	1.751
D. End turn inside diameter	4.625	5.468	4.303	4.303	
	min	min	min	min	
E. Mounting dimensions	0.022	.000	0.052	0.125	0.040
	0.042	± .012	0.072	± .010	0.020
Type of connection	Leads	Leads	Terminals	Terminals	M.S. Connector
No. of brushes	4	4	4	4	8
Stator mounting holes	4	6	6	6	4
Stator mounting B.C.	5.750	4.937	6.600	6.600	8.875

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SECTION A-A



CONNECTION

TABLE 2

The weekly run-in associated with the bearings (Paragraph 4.4.8) plus the caution mentioned (Paragraph 4.4.1) will minimize or eliminate maintenance requirements.

4.4.10 Timer

The Timer is an EXAR P/N 2240 (See Appendix X) Timing is established by varying the time constant, $T = R_{14}C_2$ (Ref: 95M16031, Fig. 5.) and by connection of terminals No. 1 through No. 8 of the timer.

With the normal + 15 volts applied to terminal 16 of the timer, the output is high. This high voltage is isolated from K_1 (Ref: 95M16028) Fig. 6 by K_6 . As "timer start" is initiated, the timer output drops to zero and time delay K_6 closes after approximately 0.1 seconds. After the timer sequence is completed, the timer output goes "high", triggering Q_1 (Ref: 95M16031) Fig. 4 and applying voltage to K_1 , thus removing power from the servo system.

4.4.11 Other

All other components such as relays, resistors, capacitors, etc., will require no maintenance and should simply be replaced upon failure, which is unlikely.

5.0 GROUND PROCEDURES

5.1 Battery Activation - See Appendix V

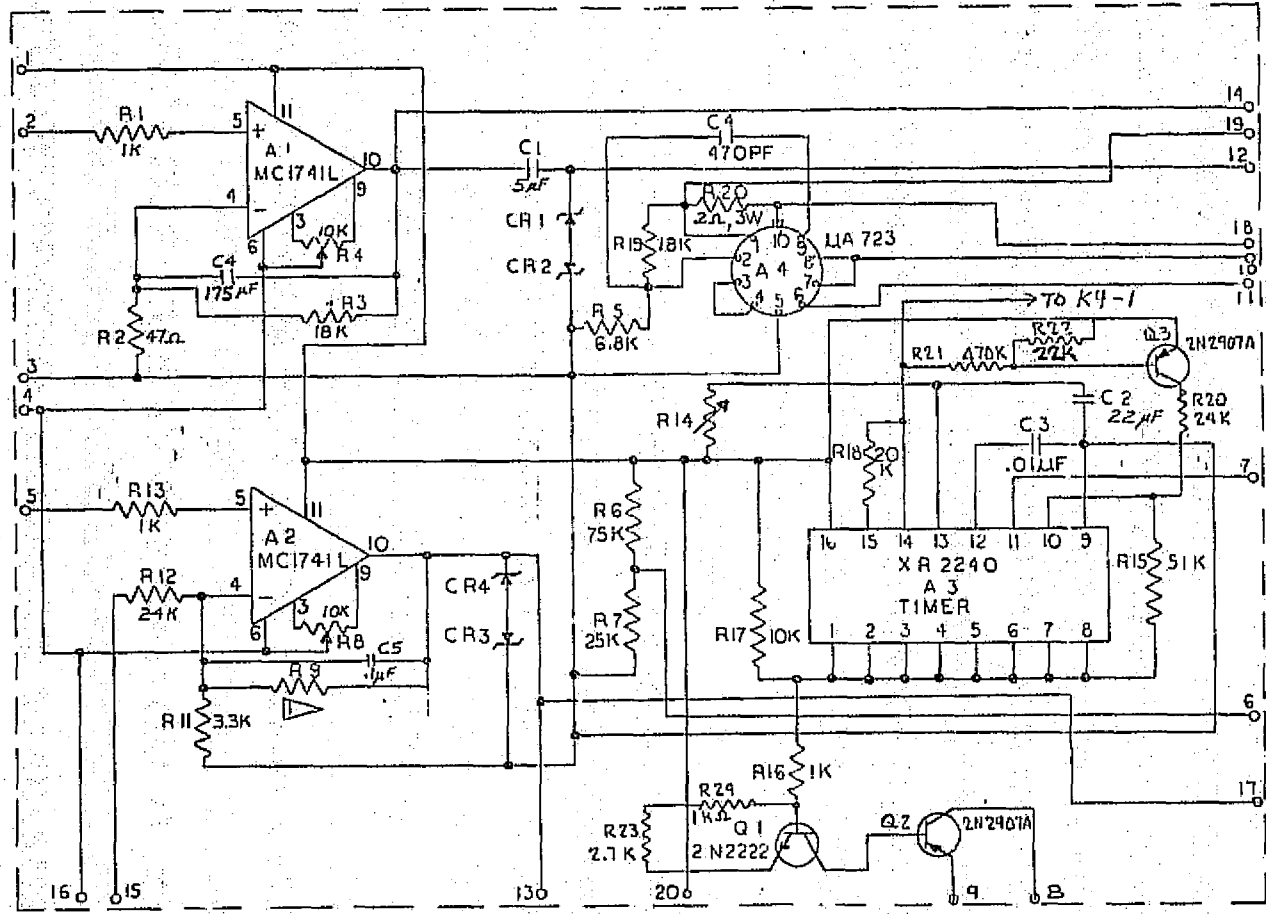
5.2 System Checkout - See Paragraph 4.0

5.3 Assembly and Disassembly - See Appendix XI

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PART NO.		REV. NO.		REVISIONS		DATE	APPROVAL
				ADDED R22, R23, R24			6/12/71
				1. R22, R23, R24			

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NOTES:
 R9 VALUE 51K TO 56K

F16 5

		UNLESS OTHERWISE SPECIFIED			ORIGINAL DATE OF DRAWING 4 NOV. 1971		ELECTRICAL SCHEMATIC PC 1			GEORGE C. MARSHALL SPACE FLIGHT CENTER								
SEE ENGINEERING RECORDS		DIMENSIONS ARE IN INCHES			DESIGNED BY <u>TALLET</u> CHECKED					NATIONAL AERONAUTICS AND SPACE ADMINISTRATION HUNTSVILLE, ALABAMA								
		TOLERANCES ON			CHECKED													
		FRACTIONS			DRAWN													
		MATERIAL			SUBMITTED		DWG SHEET C			95M16031A								
		NEAT TREATMENT			APPROVED		WEIGHT CHECKER						DATE			CODE		
NEXT ASSY		USED ON																
APPLICATION		FINAL PROTECTIVE FINISH			DIRECTOR		SCALE			UNIT WEIGHT			SHEET 1 OF 1					

6 SYSTEM #1 REPLACE MC1741L WITH
T05 CASE

MC1741L	3	4	5	6	9
---------	---	---	---	---	---

MC1741L	3	4	5	6	9	10	11
T0.5	1	2	3	4	5	6	7

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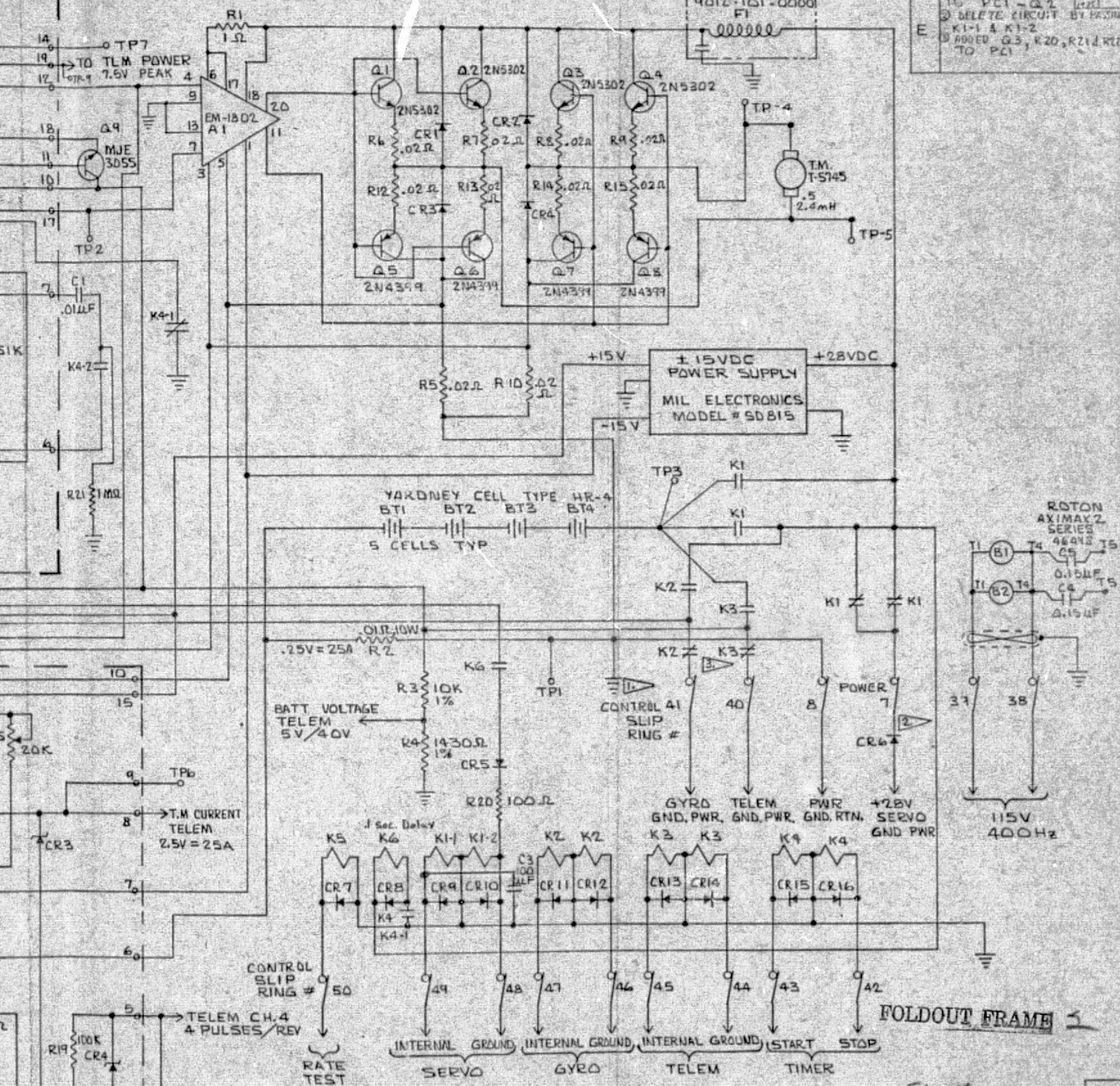
LDOUT FRAME

NOTES

1. THIS IS A SINGLE POINT GND ISOLATED FROM THE PLATFORM & BROUGHT OUT THRU CENTER OF SHAFT & ATTACH TO TERM ON EXPERIMENT PKG.
2. SUPPLIED AS PART OF GSE
3. K1, K2 & K3 SHOWN IN "GROUND" POSITION, K4 SHOWN IN "STOP" POSITION.
4. TP = TEST POINT.

PART NO.		ZONE	SYM	DESCRIPTION	DATE	APPROVAL
				REVISED & REDRAWN	1/16/79	
				REVISED	2/20/79	

SYM	DESCRIPTION	DATE	APPROVAL
ADD'D	2N2907A TO PC1-Q2	1/16/79	
DEL'TE	CIRCUIT BY PASSING K1-1 & K1-2	2/20/79	
ADD'D	Q3, R20, R21 & R22 TO PC1	2/20/79	



UNLESS OTHERWISE SPECIFIED		ORIGINAL DATE OF DRAWING		ELECTRICAL SCHEMATIC		GEORGE C. MARSHALL SPACE FLIGHT CENTER	
DIMENSIONS ARE IN INCHES		1/24/79		NON-SPIN PLATFORM		NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	
TOLERANCES ON FRACTIONS		CHECKER		WEIGHT CHECKER		HUNTSVILLE, ALABAMA	
MATERIAL		ENGINEER		DATE		SYNO SIZE	
HEAT TREATMENT		SUBMITTED		CODE		D 95M16028	
NEXT ASSY USED ON		APPROVED		UNIT WEIGHT		SHEET	
APPLICATION		DIRECTION				1 OF 1	

6.0 Flight Procedures

There are no Flight Procedures associated with this article.

7.0 Conclusions

Stress analysis performed by both NASA and ASL personnel show that the structural portion of the NSP exceeds the design requirements defined by MSFC-HDBK-505 by sufficient margin to conclude that all structural requirements will be met. (See paragraph 2.1)

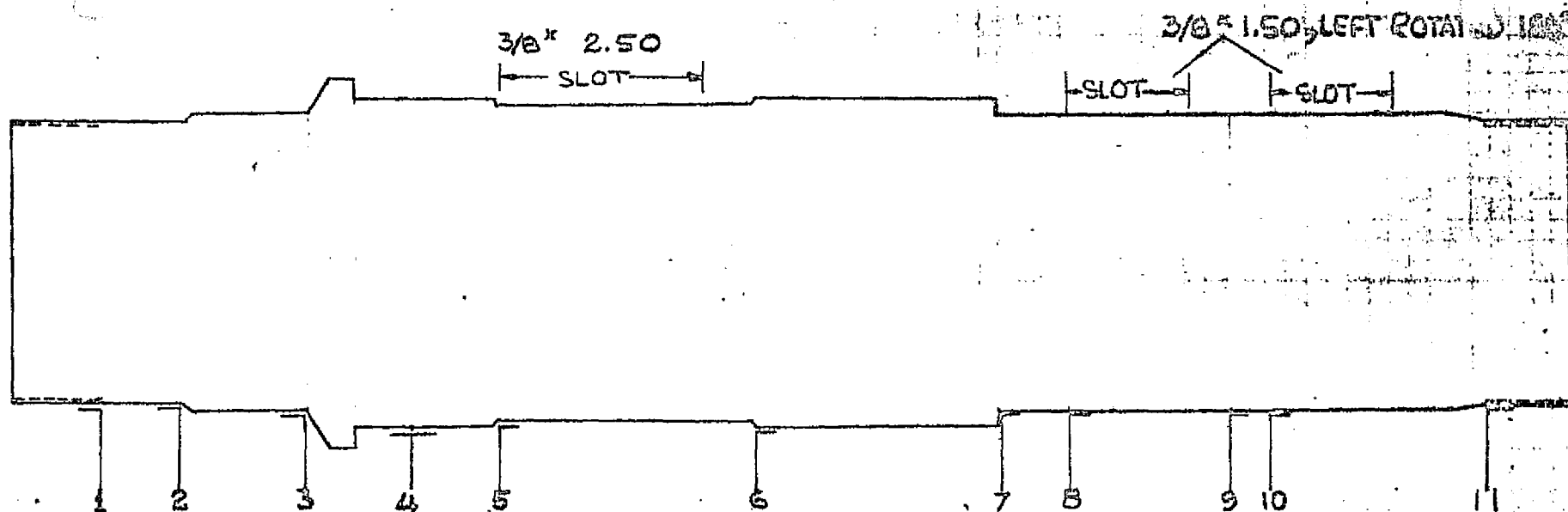
Spin tests to 200 RPM showed that specification requirements were exceeded by approximately a factor of ten. Spin tests to 300 RPM showed the platform to be well within specification requirements. From the above, it can be concluded that all functional requirements have been met.

All parts or sub-assemblies used in the NSP have been qualified by similarity or by direct flight usage or are not subject to deleterious effects of vibration, pressure, temperature, etc., and can, thus, be considered qualified for the intended usage.

Good EMI-RFI design techniques have been employed by means of utilizing twisted and shielded wire in critical circuits and by placing an RFI filter electrically close to the noise source (torque motor). The battery itself will also serve as an excellent RFI filter. The above, coupled with the fact that the noise frequencies that could be generated by the NSP are so far removed from those that could effect the telemetry sub-system, lead to the conclusion that all EMI-RFI requirements have been met.

Astro-Space Laboratories considers that all specification requirements have been met or exceeded and has, in fact, fulfilled the requirements on Contract NAS8-30528.

The results of tests performed on System #1 at MSFC are reported in a memo dated 25 March, 1975, and are included as Appendix VI.



MATERIAL 17-4 PH, H1025

$F_{TY} = 145,000 \text{ PSI}$

$F_{TU} = 155,000 \text{ PSI}$



STA NO	STA (IN)	OD (IN)	ID (IN)	I (IN ⁴)	M (IN LB)	F_b (PSI)	F_{SY}	F_{SU}
1	-6.65	3.27	2.92	2.0439	118,000	94,393	1.53	1.64
2	-5.55	3.375	3.04	2.176	123,000	95,387	1.52	1.62
3	-4.00	3.50	3.17	2.409	130,000	94,438	1.53	1.64
4	-3.00	3.936	3.68	2.778	135,000	95,637	1.51	1.62
5	-2.00	3.90	3.60	2.9068	134,000	92,751	1.56	1.67
6	1.50	3.936	3.68	2.778	132,000	93,512	1.55	1.65
7	4.45	3.50	3.19	2.283	123,000	94,284	1.53	1.64
8	5.50	3.50	3.16	2.288	118,000	93,451	1.55	1.65
9	7.45	3.50	3.24	1.956	108,000	96,626	1.50	1.60
10	8.00	3.50	3.21	1.9956	105,000	95,340	1.52	1.62
11	10.40	3.27(?)	3.00	1.636	94,000	93,943	1.54	1.64

ECF/EP44
10/23/74

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SHAFT OPTIMIZATION [FOR MAX PAYLOAD]

GCT/L.T.-
10/22/74

1/9

MATERIAL: 17-4 PH H 1025

$$F_{TU} = 155 \text{ KSI}$$

$$F_{TY} = 145 \text{ KSI}$$

POINT 1, STA -6.65 M = 118,000 IN·LB

OD = 3.27 IN

$$f_b = \frac{MC}{I} ; I = \frac{\pi}{64} (D_o^4 - D_i^4)$$

$$I = \frac{MC}{f_b} = \frac{M D_o/2}{145,000/1.5} = \frac{MD_o}{193333} = 2$$

$$D_i = \sqrt[4]{-\frac{64I}{\pi} + D_o^4} = 2.9289$$

$D_i = 2.92 \text{ IN @ POINT 1.}$

$$I = \frac{\pi}{64} (3.27^4 - 2.92^4) \text{ IN}^4$$

$$I = 2.0439 \text{ IN}^4$$

$$f_b = \frac{(118,000)(1.635)}{2.0439} \text{ PSI}$$

$$f_b = 94393 \text{ PSI}$$

$$F.S._Y = \frac{145,000}{94393} = 1.53$$

$$F.S._U = \frac{155,000}{94393} = 1.64$$

QST 10-10 4/9
10/22/74

POINT 2 STA -5.55 M = 123,000 IN·LB

$$D_o = 3.375 \text{ IN}$$

$$D_i = 3.04 \text{ IN}$$

$$I = \frac{\pi}{64} (3.375^4 - 3.04^4) \text{ IN}^4$$

$$I = 2.176 \text{ IN}^4$$

$$f_b = \frac{(123,000)(1.6875)}{2.176} \text{ PSI}$$

$$f_b = 95387 \text{ PSI}$$

$$F.S._Y = \frac{145,000}{95387} = 1.52 ; F.S._U = \frac{155,000}{95387} = 1.62$$

POINT 3 STA -4.00 M = 130,000 IN·LB

$$D_o = 3.50 \text{ IN}$$

$$D_i = 3.17 \text{ IN}$$

$$I = \frac{\pi}{64} (3.50^4 - 3.17^4) \text{ IN}^4$$

$$I = 2.409 \text{ IN}^4$$

$$f_b = \frac{(130,000)(1.75)}{2.409} \text{ PSI}$$

$$f_b = 94,438 \text{ PSI}$$

$$F.S._Y = \frac{145,000}{94,438} = 1.53 ; F.S._U = \frac{155,000}{94,438} = 1.64$$

GCF/EP42

10/22/74

3/9

POINT 4 STA - 3.00

M = 135,000 IN·LB

$$OD = 3.936 \text{ IN}$$

$$D_i = 3.68 \text{ IN}$$

$$I = \frac{\pi}{64} (3.936^4 - 3.68^4) \text{ IN}^4$$

$$I = 2.778 \text{ IN}^4$$

$$F_b = \frac{(135,000)(1.968)}{2.778} \text{ PSI}$$

$$F_b = 95637 \text{ PSI}$$

$$F.S._Y = \frac{145,000}{95637} = 1.51$$

$$F.S._U = \frac{155,000}{95637} = 1.62$$

POINT 5 - STA - 2.60

M = 134,000 IN·LB

$$OD = 3.90$$

$$D_i = 3.60$$

$$A_1 = \frac{\pi}{4} (3.90^2 - 3.60^2) \text{ IN}^2$$

$$A_1 = 1.767 \text{ IN}^2$$

$$A_2 = -(0.375)(.15) \text{ IN}^2$$

$$A_2 = -.05625 \text{ IN}^2$$

$$d = \frac{-(1.875)(.05625)}{1.767 - .05625} \text{ IN}$$

$$d = -.062 \text{ IN}$$

$$I_1 = \frac{\pi}{64} (3.90^4 - 3.60^4) + (1.767)(.062)^2$$

$$I_1 = 3.118 \text{ IN}^4$$

$$I_2 = \frac{1}{12} (.375)(.15)^3 + (.05625)(1.937)^2$$

$$I_2 = .2112 \text{ IN}^4$$

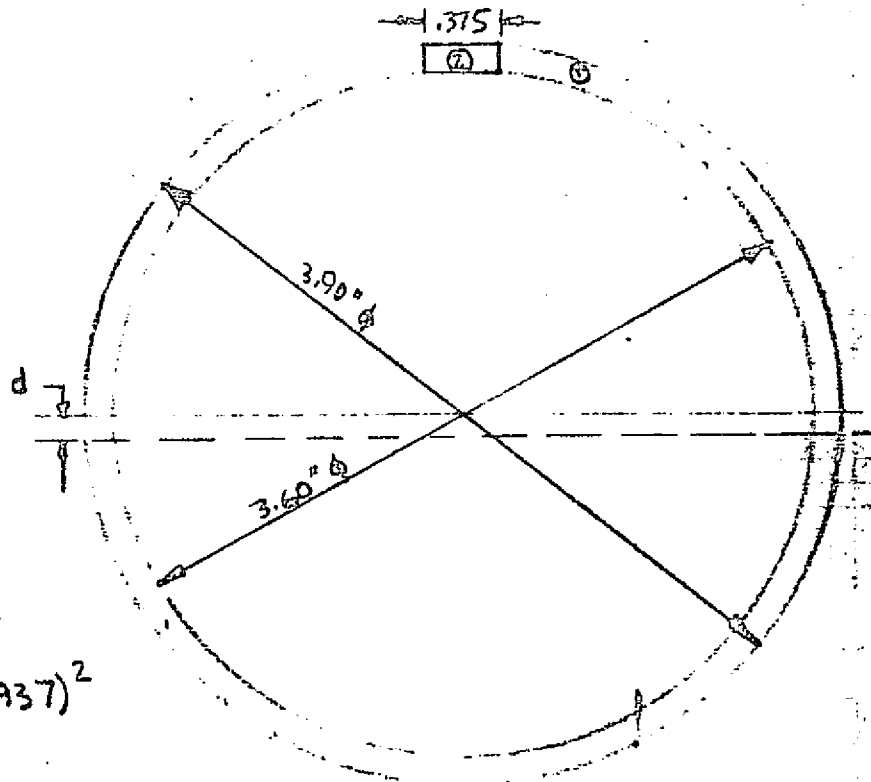
$$I = I_1 - I_2 = 2.9068 \text{ IN}^4$$

$$F_b = \frac{(134,000)(2.012)}{2.9068} \text{ PSI}$$

$$F_b = 92751 \text{ PSI}$$

$$F.S._Y = \frac{145,000}{92751} = 1.56$$

$$F.S._U = \frac{155,000}{92751} = 1.67$$



GCT/CI - 4/9
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POINT 6 STA 1.50

M = 132,000 IN LB

$$OD = 3.936 \text{ IN}$$

$$D_i = 3.68 \text{ IN}$$

$$I = \frac{\pi}{64} (3.936^4 - 3.68^4)$$

$$I = 2.778 \text{ IN}^4$$

$$f_b = \frac{(132,000)(1.968)}{2.778} \text{ PSI}$$

$$f_b = 93512 \text{ PSI}$$

$$FS_Y = \frac{145,000}{93512} = 1.55 \quad ; \quad FS_U = \frac{155,000}{93512} = 1.65$$

POINT 7 STA 4.45 M = 123,000 IN LB

$$OD = 3.50 \text{ IN}$$

$$D_i = 3.19 \text{ IN}$$

$$I = \frac{\pi}{64} (3.50^4 - 3.19^4) \text{ IN}^4$$

$$I = 2.283 \text{ IN}^4$$

$$f_b = \frac{(123,000)(1.75)}{2.283}$$

$$f_b = 94284 \text{ PSI}$$

$$FS_Y = \frac{145,000}{94284} = 1.53 \quad ; \quad FS_U = \frac{155,000}{94284} = 1.64$$

GLF/20-40 5/9
10/23/74

POINT B. STA 5.50

M = 110,000 IN LB

OD = 3.50 IN.

TRY $D_i = 3.19$ IN

$$A_1 = \frac{\pi}{4} (3.50^2 - 3.19^2) \text{ IN}^2$$

$$A_1 = 1.6288 \text{ IN}^2$$

$$A_2 = -(.375)(.155) \text{ IN}^2$$

$$A_2 = -.058 \text{ IN}^2$$

$$d = \frac{-(.058)(1.6725)}{1.6288 - .058}$$

$$d = -.062 \text{ IN}$$

$$I_1 = \frac{\pi}{64} (3.50^4 - 3.19^4) + (1.6288)(.062)^2$$

$$I_1 = 2.289 \text{ IN}^4$$

$$I_2 = \frac{1}{12} (.375)(.155)^3 + (.058)(1.7345)^2$$

$$I_2 = .1746 \text{ IN}^4$$

$$I = I_1 - I_2 = 2.114 \text{ IN}^4$$

$$f_b = \frac{(110,000)(1.812)}{2.114} \text{ PSI}$$

$$f_b = 101,143 \text{ PSI} = 7 \text{ F.S. } \gamma = 1.43 \text{ TOO LOW!}$$

TRY $D_i = 3.16$ IN

$$A_1 = \frac{\pi}{4} (3.50^2 - 3.16^2) \text{ IN}^2$$

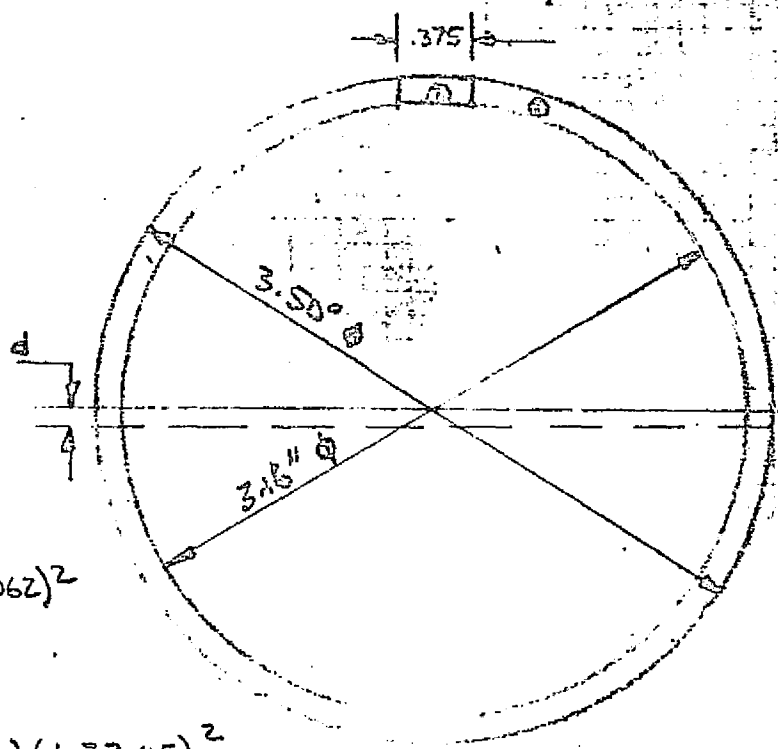
$$A_1 = 1.778 \text{ IN}^2$$

$$A_2 = -(.375)(.17) \text{ IN}^2$$

$$A_2 = -.06375 \text{ IN}^2$$

$$d = \frac{-(.06375)(1.665)}{1.778 - .06375} \text{ IN}$$

$$d = -.062$$



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10/23/74

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$$I_1 = \frac{\pi}{64} (3.50^4 - 3.16^4) + (1.778)(.062)^2$$

$$I_1 = 2.478 \text{ IN}^4$$

$$I_2 = \frac{1}{12} (.375)(.17)^3 + (.06375)(1.727)^2$$

$$I_2 = .19 \text{ IN}^4$$

$$I = I_1 - I_2 = 2.288 \text{ IN}^4$$

$$f_b = \frac{(118,000)(1.812)}{2.288} \text{ PSI}$$

$$f_b = 93451 \text{ PSI}$$

$$F.S._Y = \frac{145,000}{93451} = 1.55$$

$$F.S._U = \frac{155,000}{93451} = 1.65$$

POINT 9 STA 7.45 M = 108,000 IN LB

OD = 3.50 IN

DI = 3.24 IN

$$I = \frac{\pi}{64} (3.50^4 - 3.24^4) \text{ IN}^4$$

$$I = 1.956 \text{ IN}^4$$

$$f_b = \frac{(108,000)(1.75)}{1.956} \text{ PSI}$$

$$f_b = 96,626 \text{ PSI}$$

$$F.S._Y = \frac{145,000}{96,626} = 1.50$$

$$F.S._U = \frac{155,000}{96,626} = 1.60$$

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POINT 10. STA 8.0 M = 105,000 IN·LB

OD = 3.50 IN

TRY $D_i = 3.19$

THEN FROM FIRST TRY PAGES WE HAVE

$$I = 2.114 \text{ IN}^4$$

$$f_b = \frac{(105,000)(1.812)}{2.114} \text{ PSI}$$

$$f_b = 90,000 \text{ PSI}$$

$$F.S. = \frac{145,000}{90,000} = 1.61, \text{ TOO HIGH}$$

TRY $D_i = 3.22 \text{ IN}$

$$A_1 = \frac{\pi}{4}(3.50^2 - 3.22^2) \text{ IN}^2$$

$$A_1 = 1.4778 \text{ IN}^2$$

$$A_2 = -(.375)(.14) \text{ IN}^2$$

$$A_2 = -.0525 \text{ IN}^2$$

$$d = \frac{-(.0525)(1.68)}{1.4778 - .0525} \text{ IN}$$

$$d = -.062 \text{ IN}$$

$$I_1 = \frac{\pi}{64}(3.50^4 - 3.22^4) + (1.4778)(.062)^2$$

$$I_1 = 2.0947 \text{ IN}^4$$

$$I_2 = \frac{1}{12}(.375)(.14)^3 + (.0525)(1.742)^2$$

$$I_2 = .1594 \text{ IN}^4$$

$$I = I_1 - I_2 = 1.9353 \text{ IN}^4$$

$$f_b = \frac{(105,000)(1.812)}{1.9353}$$

$$f_b = 98,310 \text{ PSI} ; F.S. = \frac{145,000}{98,310} = 1.47 \text{ TOO LOW!}$$

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$$\text{TRY } D_1 = 3.21 \text{ IN}$$

$$A_1 = \frac{\pi}{4} (3.50^2 - 3.21^2) \text{ IN}^2$$

$$A_1 = 1.5283 \text{ IN}^2$$

$$A_2 = - (0.375)(.145) \text{ IN}^2$$

$$A_2 = -.054375 \text{ IN}^2$$

$$d = - \frac{(.054375)(1.6775)}{1.5283 - .054375}$$

$$d = -.062 \text{ IN}$$

$$I_1 = \frac{\pi}{64} (3.50^4 - 3.21^4) + (1.5283)(.062)^2$$

$$I_1 = 2.1602 \text{ IN}^4$$

$$I_2 = \frac{1}{12} (.375)(.145)^3 + (.054375)(1.7395)^2$$

$$I_2 = .1646$$

$$I = I_1 - I_2 = 1.9956 \text{ IN}^4$$

$$f_b = \frac{(105,000)(1.812)}{1.9956} \text{ PSI}$$

$$f_b = 95,340 \text{ PSI}$$

$$F.S._Y = \frac{145,000}{95,340} = 1.52 \quad ; \quad F.S._U = \frac{155,000}{95,340} = 1.62$$

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POINT II STA 10.40 M = 94,000 IN LB.

$$OD = 3.27$$

$$D_k = 3.00$$

$$I = \frac{\pi}{64} (3.27^4 - 3.00^4) \text{ IN}^4$$

$$I = 1.636 \text{ IN}^4$$

$$f_b = \frac{(94,000)(1.635)}{1.636} \text{ PSI}$$

$$f_b = 93943 \text{ PSI}$$

$$FS_Y = \frac{145,000}{93943} = 1.54 \quad ; \quad FS_U = \frac{155,000}{93943} = 1.64$$

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APPENDIX II

Non-Spin Platform - Stress Analysis

Bearing Retaining Nut

The bearing retaining nut is used to hold the platform bearings, and must carry the axial load due to acceleration. The shear strength of the threads on the steel shaft is the limiting factor in the load carrying strength.

The shear strength of the threads, as calculated below, is 8.814×10^5 lbf, which is equivalent to 2203.5 g's acceleration for an assumed 400 lb. platform load. This gives a safety factor of 36.7 for a 60 g shock load.

Strength calculation

Material: 17-4 PH

Shear strength: 130,000 lbf/in²

Threads: 3/4" length, 12 threads per inch

Locknut: #AN20

Maximum minor diameter: 3.8368

Thread height: $H = 0.072169$

Root thickness at maximum minor diameter = 0.0625"

No. of engaged threads, $n = 3/4 \times 12 = 9$

Total thread length, $l = 9 \times \pi \times 3.8368 = 108.48"$

Shear area, $A = 108.48 \times 0.0625" = 6.78 \text{ in}^2$

$$\text{Shear strength} = 130,000 \times 6.78 = 8.814 \times 10^5$$

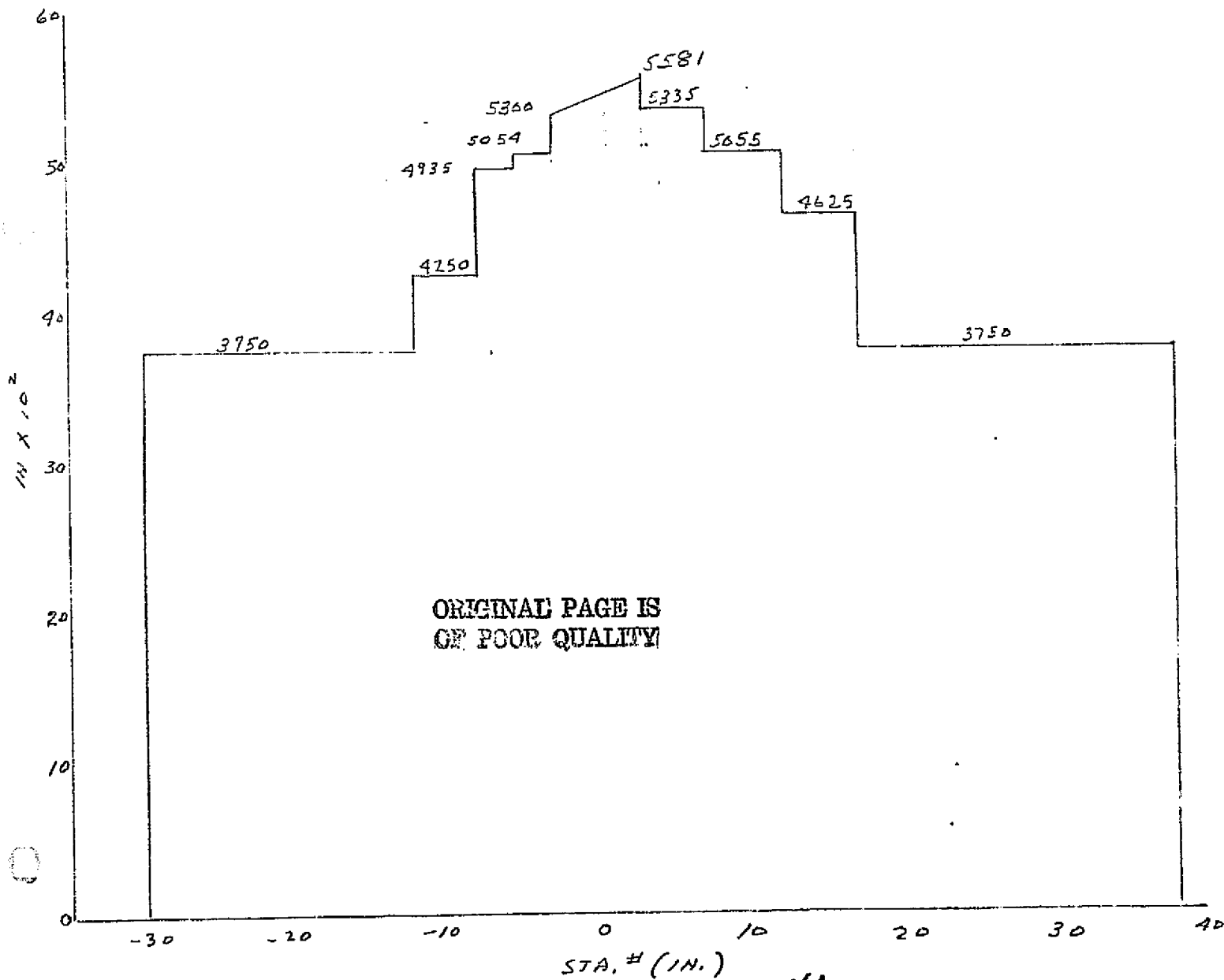
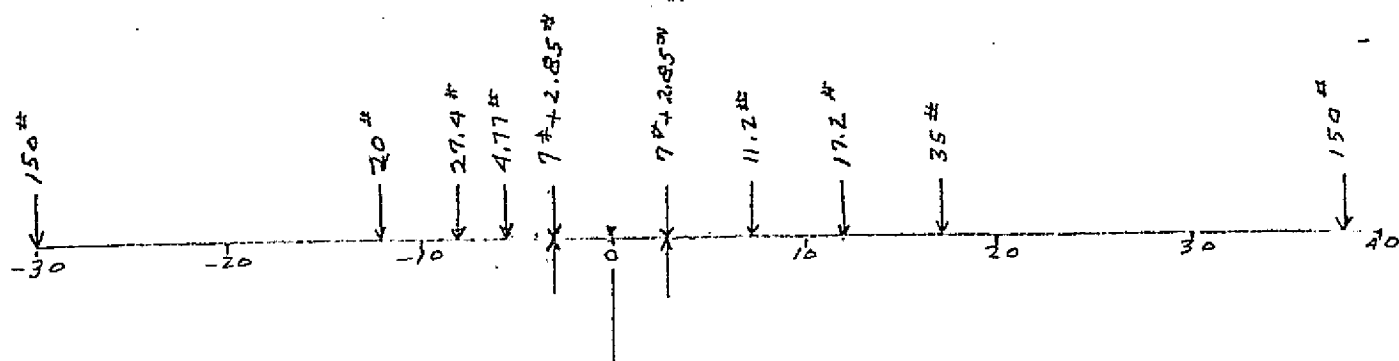
$$\text{Accelerations (400 lb platform)} = \frac{8.814 \times 10^5}{400} = 2203.5 \text{ g's}$$

$$\text{Safety factor} = \frac{2203.5}{60} = 36.7$$

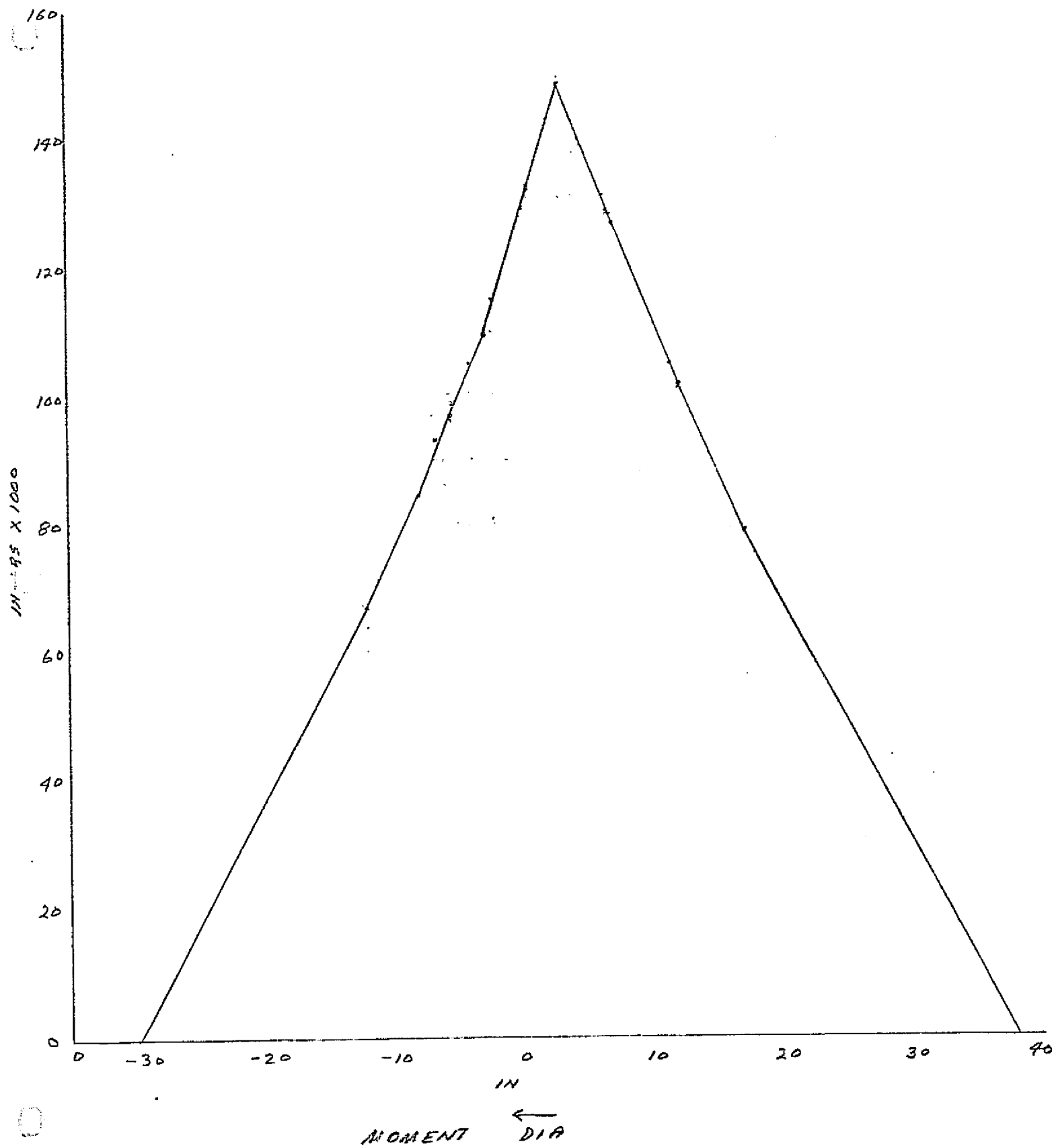
NOTE: "The shear area of the external thread is the effective area at a diameter equal to the maximum minor diameter of the internal thread." NBS Handbook H-28(1957)

APPENDIX III

①
8/28/74



8/28/74 (2)



(3)

8/28/74

MOMENT CALCULATIONS

$$M_{(-12)} = 150(25)(30-12) = 67500 \text{ IN} \cdot \text{ft}$$

$$M_{(-8)} = (150)(25)(30-8) + (20)(25)(4) = 84500 \text{ IN} \cdot \text{ft}$$

$$M_{(-5.5)} = (150)(25)(30-5.5) + (20)(25)(12-5.5) + (27.4)(25)(2.5) = 96837.5$$

$$M_{(-3)} = (150)(25)(30-3) + (20)(25)(12-3) + (27.4)(25)(5) + (4.77)(25)(2.5) = 109,473$$

$$M_{(+17)} = (150)(25)(38-17) = 78750$$

$$M_{(+12)} = (150)(25)(38-12) + (35)(25)(17-12) = 101875$$

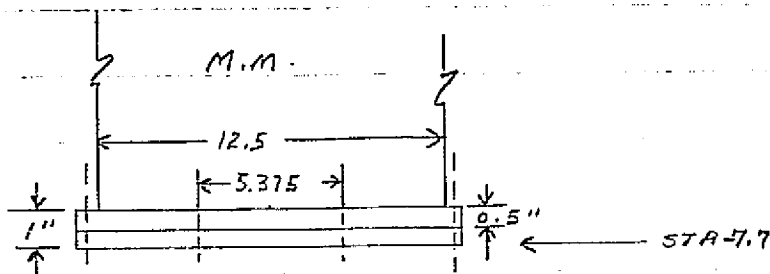
$$M_{(+7)} = (150)(25)(38-7) + (35)(25)(17-7) + 17.2(25)(12-7) = 127150$$

$$M_{(+3)} = (150)(25)(38-3) + (35)(25)(17-3) + 17.2(25)(12-3) + (11.2)(25)(4.5) = 148630$$

(4)

8/28/74

UPPER PLATFORM w/ M.M. ATTACHED



REF: CASE 5, ROARK, 4ED., PG. 242

$$\frac{y_0}{a} = \frac{5.375/2}{12.5/2} = 0.43$$

$$\beta = 1.87$$

$$S_R = \frac{\beta M}{a t^2} = \frac{(1.87)(86000)}{(6.25)(1)^2} = 27731.2 \text{ PSI}$$

$$F.S._Y = \frac{73000}{27731.2} = 2.64$$

$$F.S._U = \frac{83000}{27731.2} = 3.23$$

REF: CASE 14, ROARK, 4ED., PG 220

$$S = \frac{3W}{2\pi m t^2} \left[\frac{2a^2(m+1)}{a^2 - b^2} \ln \frac{a}{b} + (m-1) \right]$$

$$a = 12.5/2$$

$$b = 2''/2$$

$$m = 3.33$$

$$S = \frac{(3)(4935)}{2\pi(3.33)(1)^2} \left[\frac{(2)(6.25)^2(4.33)}{(6.25)^2 - (1)^2} \ln \frac{6.25}{1} + 2.33 \right]$$

$$\pi = 1''$$

$$W = 4935$$

$$= 13173.35$$

$$F.S._Y = \frac{73000}{13173.35} = 5.54$$

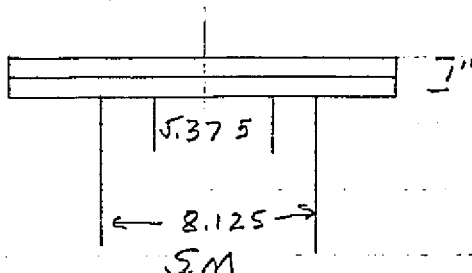
$$F.S._U = \frac{83000}{13173.35} = 6.3$$

(5)

8/28/74

LOWER PLATFORM w/ S.M. ATTACHED

REF: CASE 5, ROARK, 4 ED. PG. 242



$$\frac{r_0}{a} = \frac{5.375/2}{8.125/2} = .66$$

$$B = 0.85$$

$$S = \frac{(0.85)(102000)}{8.125/2} = 21341.5$$

$$F.S.y = \frac{73000}{21341.5} = 3.42$$

$$F.S_u = \frac{83000}{21341.5} = 3.89$$

APPENDIX TU



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812



REPLY TO
ATTN OF: EP42(74-146)

REV 1 004

TO: EH11/Mr. Yost ✓
FROM: EP41/Mr. Hopson
SUBJECT: Space Processing Sounding Rocket Bearing Loads and Shaft Stress Analysis

The shaft and bearing loads have been determined for the rearranged payload, i.e., with the Support Module (SM) forward.

Enclosure 1 shows the 1-g load distribution assumed for the maximum payload. The shaft, plates, backup rings, motor support ring, and motor weights were distributed as point loads, 25 lb. forward and 16 lb. aft. The other modules were considered as point loads at their geometric centers. R_1 and R_2 are the bearing reactions.

Enclosure 2 shows the 25-g load distribution and the bending moment diagram for the maximum payload.

Enclosure 3 shows the 1-g load distribution for the baselined payload, i.e., with the SM and the Convection Measurement Package (CMP) forward.

Enclosure 4 shows the 1-g load distribution for the SM and General Purpose Furnace (GPF) forward.

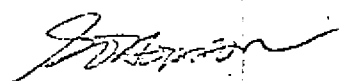
From enclosures 3 and 4, it can be seen that the maximum bearing load is smaller for the SM and CMP forward as depicted in enclosure 3. For a 25-g lateral load, the bearing load for this configuration is (25) (324.7) lb. = 8117.5 lb. This gives an acceptable factor of safety of 1.54 on yield. The configuration in enclosure 4 produces a maximum bearing load that gives an unacceptable factor of safety of 1.13 for a 25-g lateral load. Thus, enclosure 3 is the recommended arrangement for the baseline payload. For the maximum payload, the bearing loads are less since the payload c.g. lies near the center of the bearings as shown in enclosures 1 and 2.

The maximum payload dictates the shaft design. Enclosure 5 shows an optimized shaft design for a steel shaft and for the bending moment in enclosure 2.

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To prevent stress risers at the shaft diameter transitions, the increases/decreases should be accomplished with smooth radii. It is recommended that the slot between the bearings be moved aft so that it is centered between the bearings. Then the slot would be at a position of lower bending moment and away from a transition in the shaft diameter.

If this steel shaft design is chosen, a static structural test would not be required since all factors on yield are at least 1.50 which meets the requirements of letter EP42(74-102).



G. D. Hopson
Chief, Engineering Analysis Division

5 Enclosures

cc:

EP01/Mr. McCool
EP11/Mr. Pedigo
EP12/Mr. Gray
EP44/Mr. Vaniman

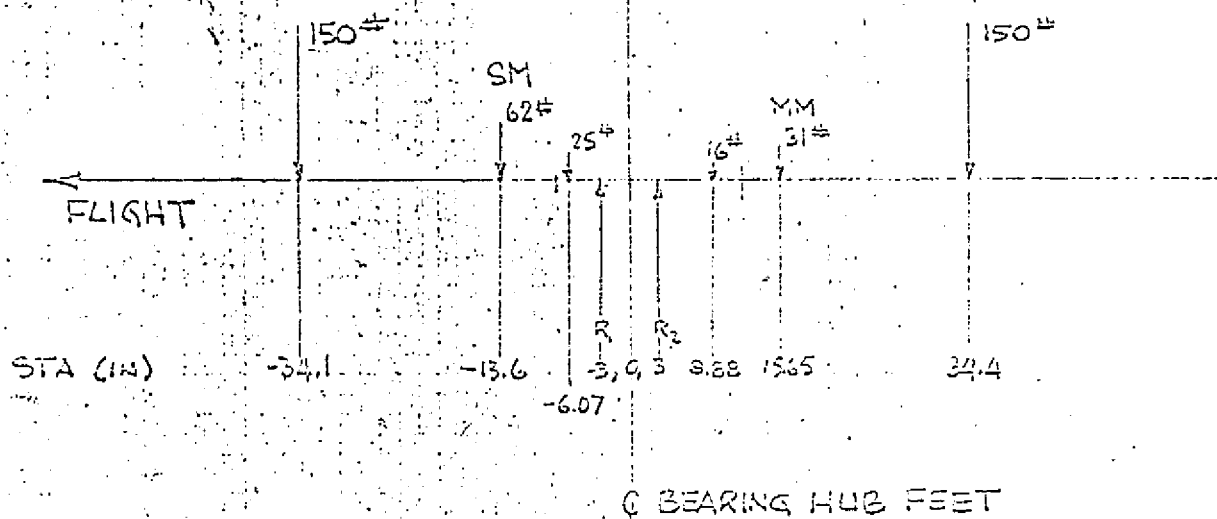
CCF/ED-2

10/15/74

SHAFT LOADS SM FORWARD

LOADS FOR 1g LATERAL

MAXIMUM PAYLOAD



$$R_1 + R_2 = 434$$

$$-3R_1 + 3R_2 = -322.72$$

$$3R_1 + 3R_2 = 1302$$

$$-3R_1 + 3R_2 = -322.72$$

$$6R_2 = 979.28$$

$$R_2 = 163.215 \text{ LB}$$

$$R_1 = 270.787 \text{ LB}$$

CG:

$$\bar{x} = \frac{(8.88)(16) + (15.65)(31) + (34.4)(150) - [(-6.07)(25) + (-13.6)(62) + (-34.1)(150)]}{434}$$

$$\bar{x} = -.744 \text{ IN}$$

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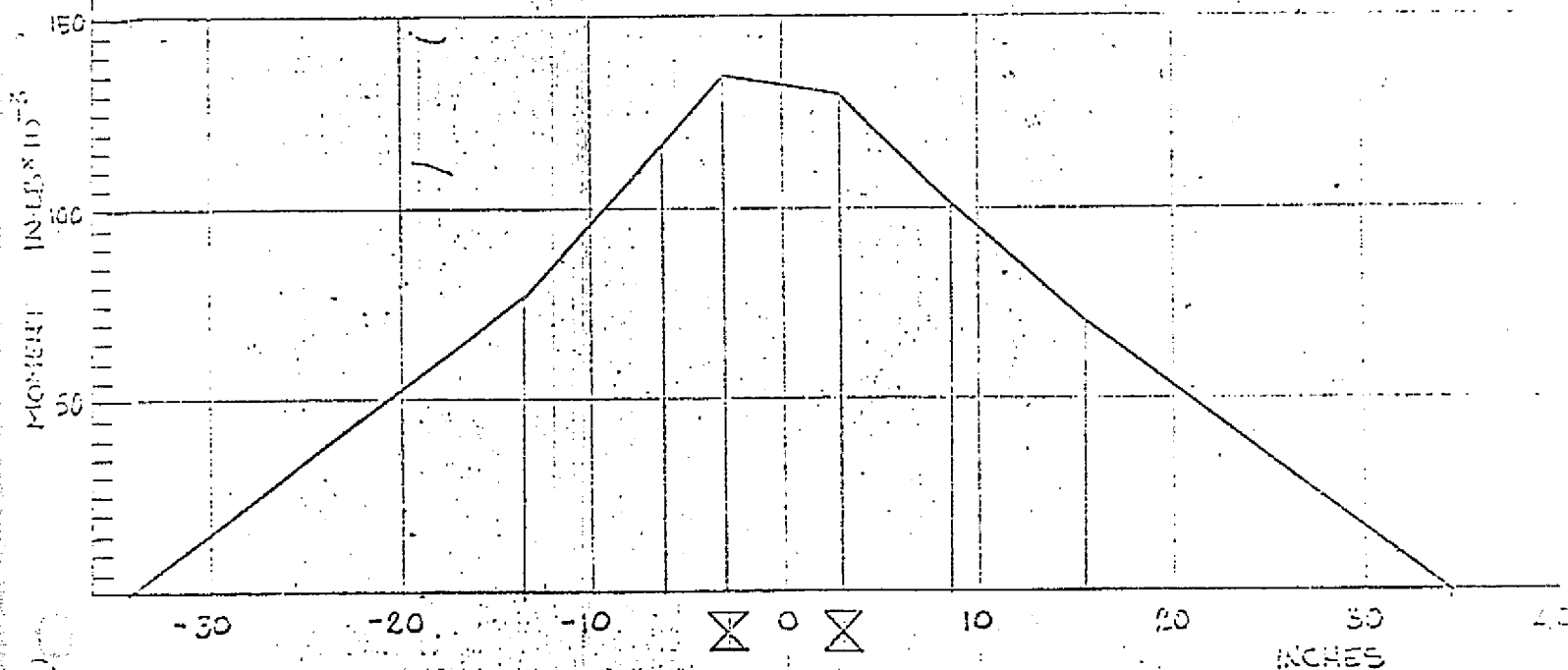
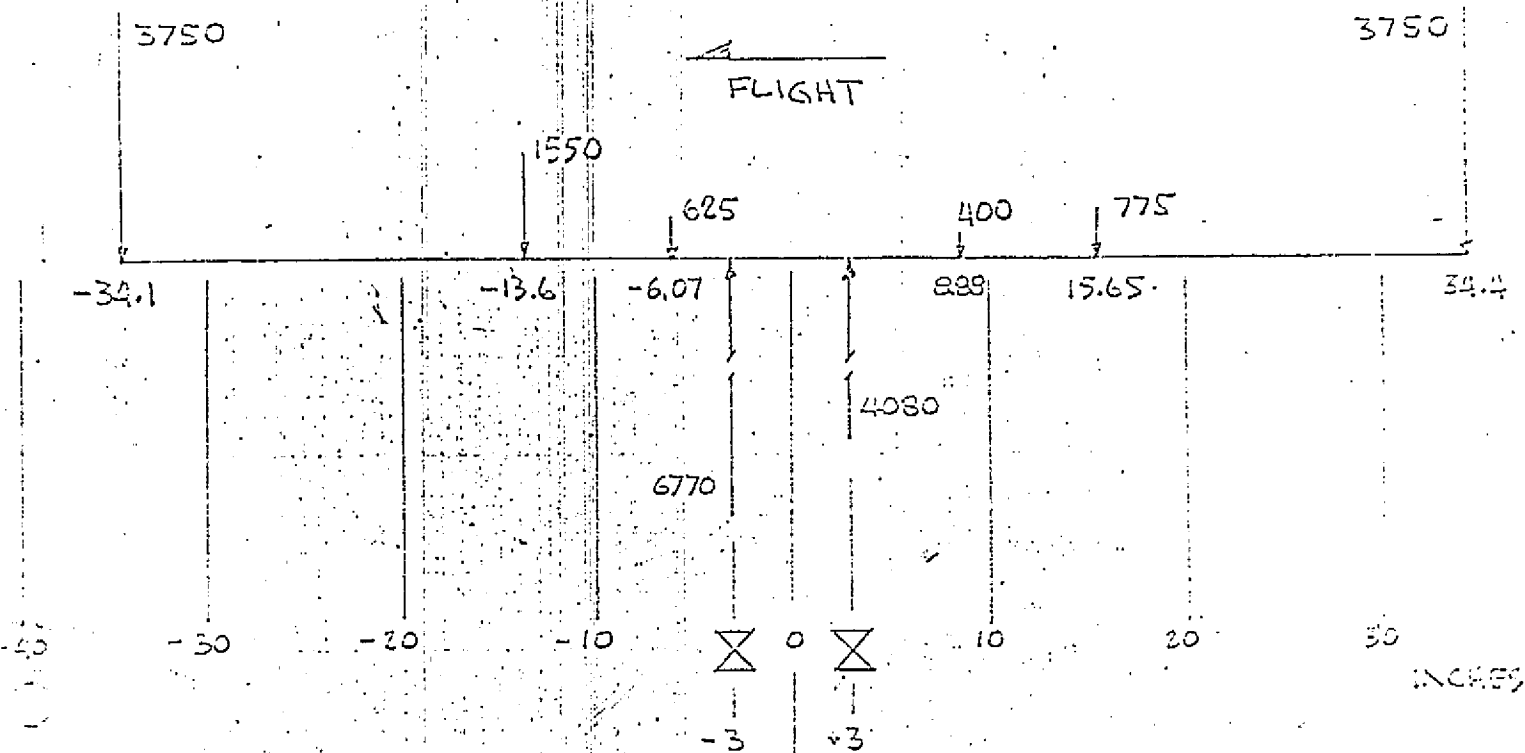
SHAFT LOADS
SM FORWARD

GCF, 10/15/74

LOADS FOR 25g LATERAL

MAXIMUM PAYLOAD

LOADS IN POUNDS



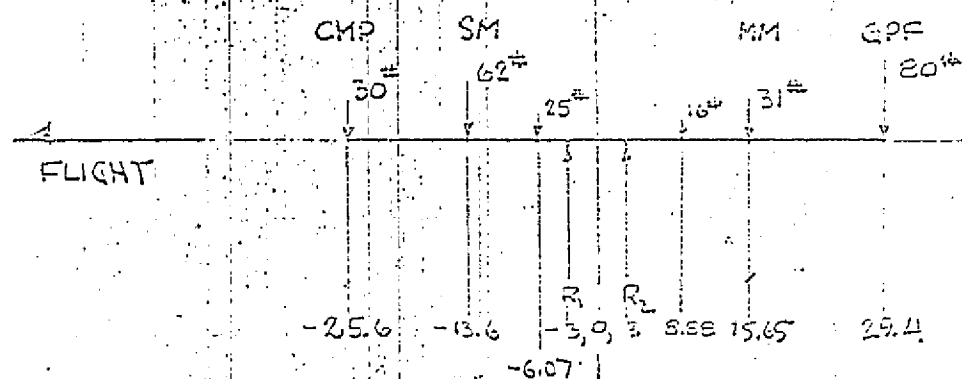
C OF BEARING HUB
MOUNTING FEET

SHAFT LOADS
CMP, SM FORWARD

GCF/EP4L
10/16/74

LOADS FOR 1g LATERAL

MSFC BASELINE PAYLOAD



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$$R_1 + R_2 = 244$$

$$-3R_1 + 3R_2 = 1216.28$$

$$3R_1 + 3R_2 = 732$$

$$-3R_1 + 3R_2 = 1216.28$$

$$6R_2 = 1948.28$$

$$R_2 = 324.7 \text{ LB}$$

$$R_1 = 80.7 \text{ LB}$$

$$\text{C.G. } \bar{X} = \frac{(8.88)(16) + (15.65)(31) + (29.4)(80) - [(6.07)(25) + (13.6)(62) + (25.6)(30)]}{244}$$

$$\bar{X} = 4.98 \text{ IN}$$

$$\begin{aligned} \text{MAX. MOMENT} &= [(26.4)(80) + (12.65)(31) + (5.93)(16)] (25 \text{ g's}) \text{ IN} \cdot \text{LB} \\ \text{IN SHAFT} &= 64,956 \text{ IN} \cdot \text{LB} \quad @ \text{ AFT BEARING} \\ \text{FOR 25 g's} & \end{aligned}$$

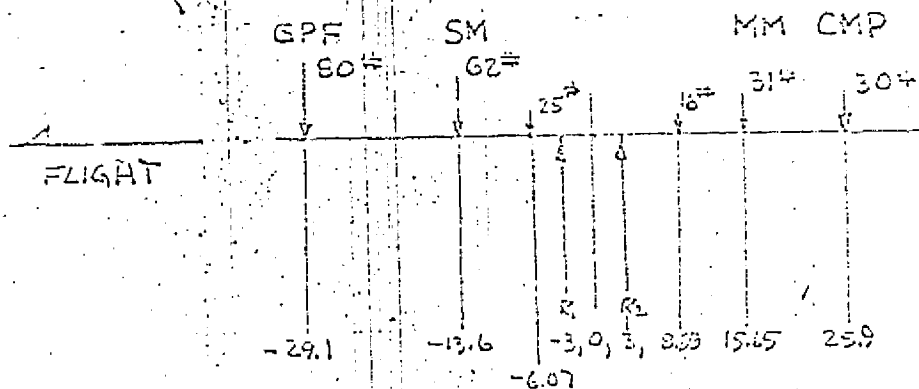
GCF/EP-2
10/16/74

SHAFT LOADS

GPF, SM FORWARD

LOADS FOR 1g LATERAL

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$$R_1 + R_2 = 244$$

$$-3R_1 + 3R_2 = -1918.72$$

$$3R_1 + 3R_2 = 732$$

$$-3R_1 + 3R_2 = -1918.72$$

$$6R_2 = -1186.72$$

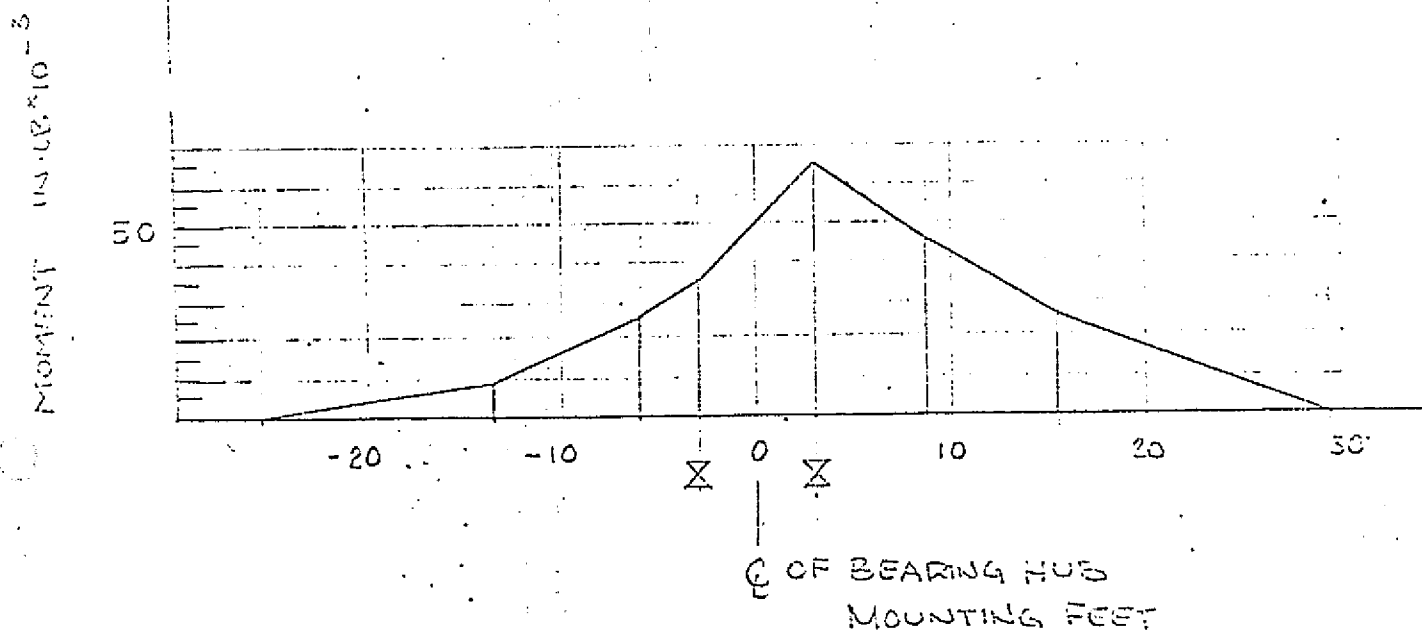
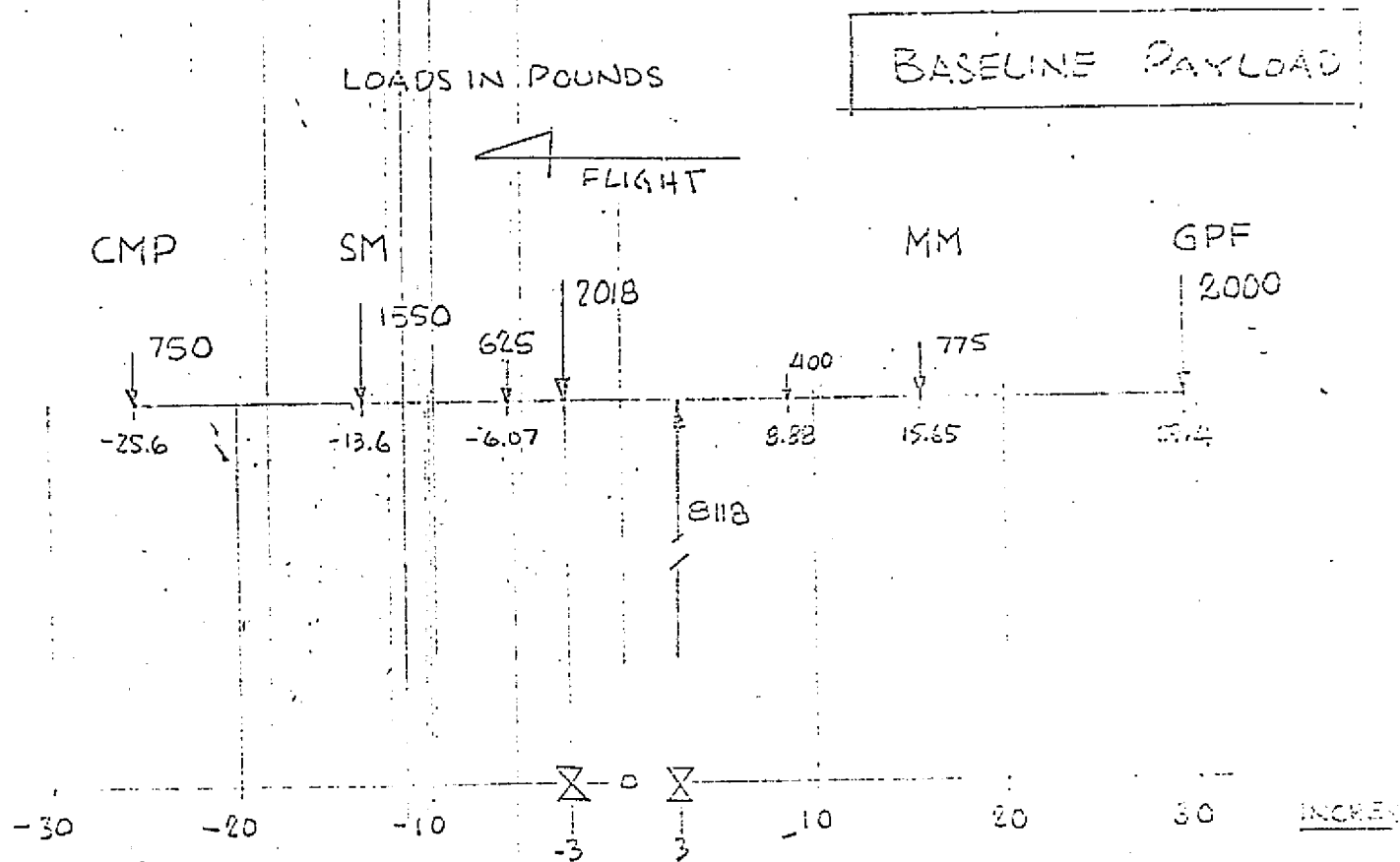
$$R_2 = -197.843$$

$$R_1 = 441.843$$

THUS THE ABOVE IS A POORER ARRANGEMENT THAN THE
BASELINE.

SHAFT LOADS
SM FORWARD
LOADS FOR 25 g LATERAL

ECF/EPAL
11/21/75



SHAFT - OPTIMIZED

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3/8" 2.50

SLOT

3/8" 1.50, LEFT ROTATED 180°

SLOT

SLOT

1 2 3 4 5 6 7 8 9 10 11

MATERIAL 17-4 PH, H1025

$F_{TY} = 145,000 \text{ PSI}$

$F_{TU} = 155,000 \text{ PSI}$

FLIGHT

STA NO	STA (IN)	OD (IN)	ID (IN)	I (IN ⁴)	M (IN LB)	F_b (PSI)	F_{SY}	F_{SU}
1	-6.65	3.27	2.92	2.0439	118,000	94,393	1.53	1.64
2	-5.55	3.375	3.04	2.176	123,000	95,387	1.52	1.62
3	-4.00	3.50	3.17	2.409	130,000	94,439	1.53	1.64
4	-3.00	3.936	3.68	2.778	135,000	95,637	1.51	1.62
5	-2.00	3.90	3.60	2.9068	134,000	92,751	1.53	1.67
6	1.50	3.936	3.68	2.778	132,000	93,512	1.55	1.65
7	4.45	3.50	3.19	2.283	123,000	94,284	1.53	1.64
8	5.50	3.50	3.16	2.283	118,000	93,451	1.55	1.65
9	7.05	3.50	3.21	1.956	103,000	93,626	1.50	1.60
10	8.00	3.50	3.21	1.9956	105,000	95,340	1.52	1.65
11	10.50	3.57	3.00	1.636	94,000	92,933	1.53	1.65

10/25/74

0

APPENDIX IV



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812



REPLY TO
ATTN OF: EP42(74-180)

DEC 6 1974

TO: EH11/Mr. Yost ✓
FROM: EP41/Mr. Hopson
SUBJECT: Stress Analysis Summary for the Space Processing Sounding Rocket
REF: 1. EP42(74-102), "Factor of Safety for the Space Processing Sounding Rocket Program"
2. EP42(74-146), "Space Processing Sounding Rocket Bearing Loads and Shaft Stress Analysis"

Enclosed is a summary of the stress analysis performed, to date, on the Space Processing Sounding Rocket program.

All components analyzed meet the requirements of reference 1 for the maximum possible payload except the end plates on the nonspin platform. It has been determined that reduction in section because of bolt holes causes the plates to be overstressed in bending for the maximum possible payload. The plates are good, however, for the MSFC baseline payload scheduled to be launched on May 20, 1975. The maximum stressed plate is the aft one, i.e., the one interfacing with the Measurement Module, and the stresses are shown in the enclosure.

If the maximum payload capability were desired at a future date, there are two options:

- a. Make the mating shaft nut and plate a monolithic piece.
- b. Proof test the flight plate connection as it is now designed.

The baseline and maximum payloads are those defined in reference 2. It is emphasized that the factors of safety in the enclosure apply only to those payloads. Any future payloads should be analyzed and approved separately.

G. D. Hopson
G. D. Hopson
Chief, Engineering Analysis Division

Enclosure

cc:
EP01/Mr. McCool
EP11/Mr. Pedigo
EP12/Mr. Gray
EP44/Mr. Vaniman

EP42

MARSHALL SPACE FLIGHT CENTER

SPACE PROCESSING SOUNDING ROCKET PROGRAM
STRESS ANALYSIS SUMMARY

NAME:

G. FAILE

DATE:

DECEMBER 4, 1974

MAJOR COMPONENTS

	ITEM	MATERIAL	ALLOWABLE STRESS	APPLIED STRESS	FAILURE MODE	F.S.Y.	F.S.U.
NONSPIN PLATFORM	SHAFT	17-4PH H1025	$F_{TU} = 155 \text{ KSI}$ $F_{TY} = 145 \text{ KSI}$	96,626 PSI	BENDING	1.50	1.60
	BEARINGS (1)	FAFNIR	12,511 LB. RADIAL	8,118 LB. RADIAL	BRINELLING	1.54	--
	AFT PLATE (2)	AL7075-T7351	$F_{TU} = 69 \text{ KSI}$ $F_{TY} = 57 \text{ KSI}$	35,723 PSI	BENDING	1.59	1.93
	BEARING HUB FEET	AL2024-T851	$F_{TU} = 67 \text{ KSI}$ $F_{TY} = 58 \text{ KSI}$	23,854 PSI	BENDING	2.43	2.80
MEASUREMENT MODULE	CANNISTER	AL2219-T87	$F_{TU} = 63 \text{ KSI}$ $F_{TY} = 52 \text{ KSI}$	5,710 PSI	BENDING	9.11	11.03
	AFT PLATE	AL6061-T6	$F_{TU} = 42 \text{ KSI}$ $F_{TY} = 35 \text{ KSI}$	3,944 PSI	BENDING	8.87	10.65
SUPPORT MODULE	END PLATE	AL2219-T87	$F_{TU} = 63 \text{ KSI}$ $F_{TY} = 52 \text{ KSI}$	31,672 PSI	BENDING	1.64	1.98
	WEB	AL2219-T87	$F_{TU} = 63 \text{ KSI}$ $F_{TY} = 52 \text{ KSI}$	7,007 PSI	BUCKLING	1.54	--

- NOTES: (1) BEARING CRITICAL LOADING OCCURS FOR MSFC BASELINE PAYLOAD
 (2) FACTORS OF SAFETY FOR MSFC BASELINE PAYLOAD
 (3) ALL DATA ARE FOR SUPPORT MODULE FORWARD AND FOR MAXIMUM PAYLOAD UNLESS OTHERWISE NOTED

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APPENDIX VI



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION GEORGE C. MARSHALL SPACE FLIGHT CENTER MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

REPLY TO
ATTN OF:

EC21 (149-75)

F. Nola, 3-4255 *FN*

March 25, 1975

TO: EC22/Mr. Fikes *EF*

FROM: EC24/Mr. Jones

SUBJECT: Non Spin Platform System # 1

The purpose of this memorandum is to specify the functional capability of the Non Spin Platform (NSP) and to establish certain operational constraints for the system. These specifications and constraints are based on performance tests run on the first NSP by EC24, on tests run on 2 cells of the NSP battery, and on information recently obtained from Goddard concerning the Black Brant spin rate and acceleration profile.

Non Spin Platform Tests

Performance tests were run on the first NSP by EC24 during the week of 3 March 1975. The only significant anomaly which was noted was the variation in drag torque as a function of speed. When the system is first turned on and the bearings and seals are at room temperature, 4 amps are required to overcome low speed friction. This corresponds to about 1.6 ft-lb and checks closely with pull scale measurements. If the speed is quickly increased to 276 RPM (the maximum specified operating speed) the current increases to 8 amps (3.3 ft-lb), and then decreases by about 1.5 amps after several minutes of running. After decreasing the speed to zero and again measuring the breakaway torque, it was indicated that the low speed friction had increased by .5 ft-lb from the initial measurement.

It is assumed that the bearing seals and changes in the seal temperature caused by the rolling friction are contributing the most to the variations in the drag torque. It is possible that these variations could become worse at the specified temperature extremes and ambient pressures. Since the system will be operating near its design limits, it is recommended that thermal vacuum performance tests be performed on the system and that these tests be coordinated with EC21 personnel.

Tests on the system indicated the motor back emf constant is .059 volts/RPM corresponding to a torque constant of .413 ft-lb/amp. Tabulated data relating to these quantities are shown in Tables 1 and 2. The motor resistance was verified to be approximately .5 ohm. The brush voltage drop plus line drop at the maximum load are approximately 1 volt. In addition, tests on a breadboard of the gimbal drive amplifier indicates an internal loss of 5.3 volts at a peak load current of 12 amps. When the system is operating at its maximum capability, the applied battery voltage is equal to the sum of the back emf voltage, the motor resistance voltage drop, the brush and line voltage loss, and the amplifier loss. Hence it is seen that the speed vs torque of the system depends directly on the battery voltage.

Battery Tests

A limited number of tests were run on two cells of the NSP battery. Curves showing the full load output voltage as a function of time are plotted in Figure 1. Both cells indicated a significantly higher output voltage for the second discharge cycle than for the first. Also, a cell tested at 35°F indicates the voltage is about .2 volts lower than at room temperature.

The cell voltage was also measured at a load of 4 amps and found to be about 1.7 volts. This current is the approximate load seen by the battery for several minutes between power transfer and lift-off.

If a sufficient number of cells are added to the battery to satisfy the high spin rate and high g loading requirements under worse case battery conditions, the pre-launch battery voltage will exceed the rating of most of the electronic assemblies in the NSP system. This condition could be accommodated by adding an overvoltage regulator. This would, however, require considerable rewiring of the system and was ruled out in lieu of tighter control of the battery. Discussions with Goddard personnel indicate there is no need to operate with a cold battery. The rocket is fired from a controlled environment and the temperature can be maintained at a nominal $75^{\circ} \pm 5^{\circ}\text{F}$. Controlling the temperature along with discharging a new set of batteries at least once before a flight would preclude the need for adding an overvoltage regulator and it is recommended that both measures be taken. It is also recommended that a complete set of battery cells (typically 20 cells) be committed to a test program to better characterize the battery performance and that these tests be coordinated with EC21 personnel.

Black Brant Performance Characteristics

In discussions with Goddard personnel it has been verified that the peak acceleration multiplied by the payload of the Black Brant rocket is a constant. Typically, these values are 12 g peak with the NSP loaded with 300 pounds of experiments.

The vehicle accelerates to its peak of 12 g's in approximately 28 seconds at which time the spin rate has reached 242 RPM. The acceleration decreases to 9.5 g's during the next 2 seconds and the spin rate increases to 260 RPM. 9.5 g's at 260 RPM is the worse case condition for the NSP. The maximum speed of 276 RPM occurs when the acceleration is near zero and this condition is not near a limit of the system.

NSP Performance

Load tests performed on the NSP bearing assembly at Astro Space Labs indicated that the rolling friction increases by approximately .55 ft-lb per 1000 pounds of load. With 9.5 g acceleration and a 300 pound payload, the bearing friction will increase approximately 1.57 ft-lb over the 3.3 ft-lb indicated by the aforementioned laboratory tests. This results in a total torque of 4.90 ft-lb which will be produced by approximately 11.9 amps in the motor. All of the quantities which determine the minimum required battery voltage are now known.

back emf	=	.059V/RPM x 260 RPM	=	15.34 volts
RI	=	.5 Ω x 11.9 amps	=	5.95 volts
Brush and Line Loss	=		=	1.00 volts
Amplifier Loss	=		=	5.30 volts

Total Battery Voltage	=	27.59 volts
-----------------------	---	-------------

With an average cell voltage of approximately 1.45 volts as indicated by the curves of Figure 1, 20 cells will produce an output of 29 volts. This results in a torque safety margin of about 23% and will not overstress electronic components during the pre-launch phase. Hence, 20 cells are recommended for the battery.

Platform Drift Tests

The NSP specification allows a maximum worse case drift of 5 RPM. Laboratory tests indicate the actual drift rate is approximately an order of magnitude less than the specification. The drift is being caused by finite servoloop gain and not by the rate gyro. The drift rate of the gyro as indicated by the steady state torquer current is approximately .05 RPM. The worse case drift of the platform could be reduced to that of the gyro by adding an electronic integrator in the servoloop. This would have aesthetic value only since the acceleration caused .5 RPM is in the micro g range and is negligible. It would also increase the power dissipation in the output transistors by about 100 watts during the prelaunch phase and is therefore not recommended.

Conclusion

The above comments and recommendations reflect our present understanding of the program and are based on tests which have been performed to date and on information which is now available. Should a change in requirement or subsequent tests on the NSP or on the batteries indicate the need for more battery cells, a total of 24 can be accommodated. EC24 is prepared to make the necessary modification to protect against high voltage.



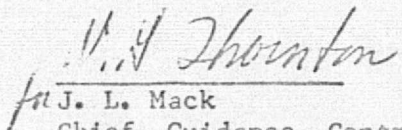
Clyde S. Jones, Sr.
Chief

Electronics and Servo-Analysis Branch

2 Enclosures:

1. Table 1 & 2
2. Chart - Battery Test

APPROVAL:



J. L. Mack
Chief, Guidance, Control &
Instrumentation Division

cc:

EC21/Mr. Mack
EC22/Mr. Fikes
EH11/Mr. Yost
PF01S/Mr. Chassay

TABLE 1

SPEED VS CURRENT AND VOLTAGE

SPEED (RPM)	MOTOR CURRENT (AMPS)	MOTOR VOLTAGE
50	5.5	6.3
100	6.2	9.2
150	6.4	12.3
200	6.4	15.4
250	6.9	18.8
300	6.5	21.4

TABLE 2

TORQUE VS CURRENT

TORQUE (FT LB)	MOTOR CURRENT (AMPS)
2.16	1.5
2.70	3.3
3.24	4.4
3.78	5.5
4.32	7.0
4.86	8.2
5.40	9.5
5.94	10.4

19

CELL VOLTAGE (VOLTS)

FIGURE NO 1
YARDNEY CELL
HR-4

$I = 11.78 \text{ AMPS}$

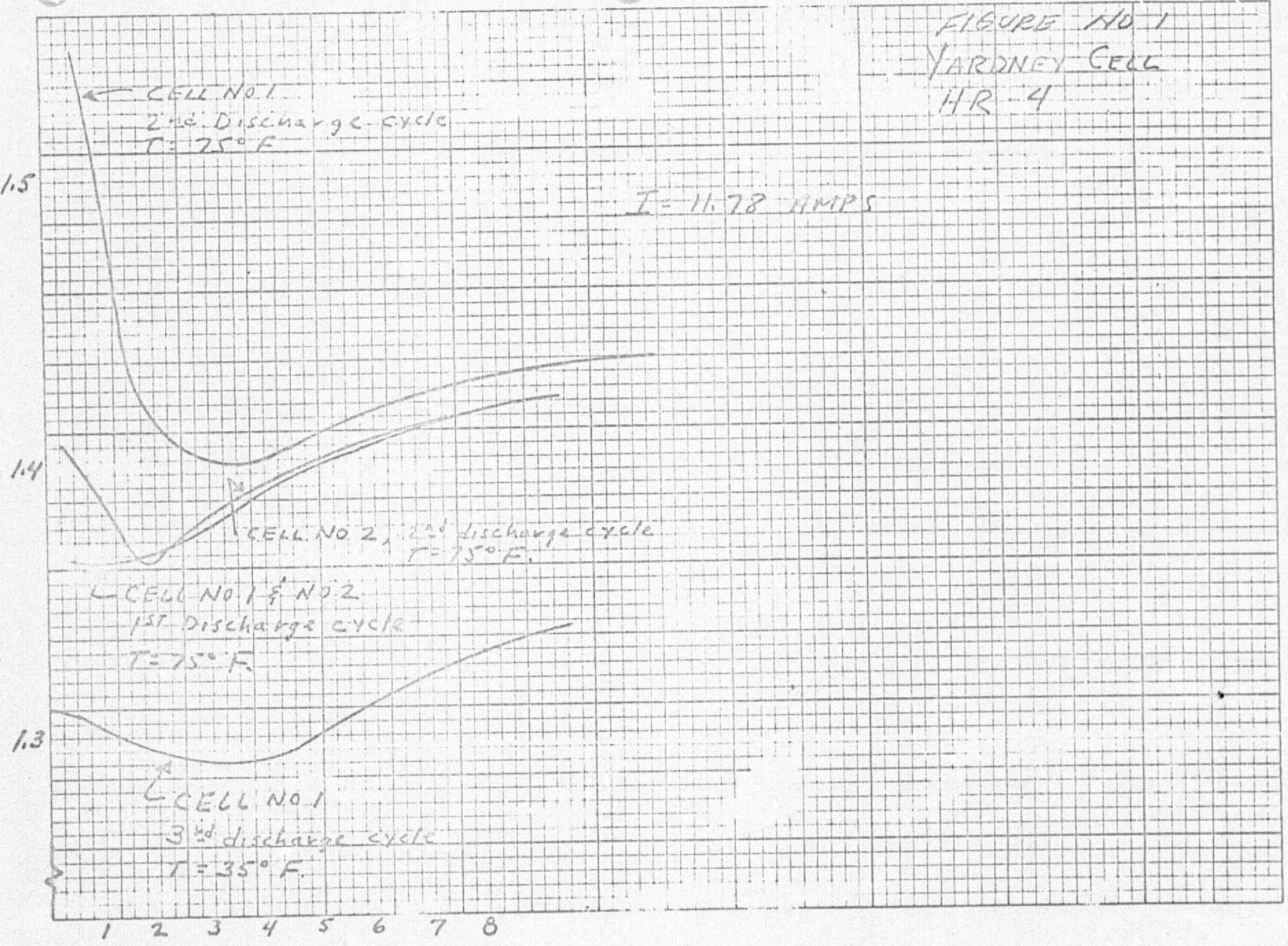
CELL NO. 1
2nd Discharge cycle
 $T = 75^\circ \text{ F}$

CELL NO. 2, 2nd Discharge cycle
 $T = 75^\circ \text{ F}$

CELL NO. 1 & NO. 2
1st Discharge cycle
 $T = 75^\circ \text{ F}$

CELL NO. 1
3rd discharge cycle
 $T = 35^\circ \text{ F}$

TIME (MINUTES) →



29 Oct 1974

Non-Spin Platform

Stress Analysis of Mounting Legs (missile to platform interface connection)

The revised configuration is shown in Fig 1. To reduce weight, the leg has been reduced in thickness from $\frac{1}{2}$ " to $\frac{3}{8}$ ", and the two gussets have been replaced by a single gusset.

Mounting is by two bolts per leg, ($\frac{5}{16}$ " DIA) rated at 18,000 lbf. If these bolts are torqued to a 6000 lbf stress per bolt, the connection will withstand $6000 \times 8 = 48,000$ lbf in the axial direction. The force generated under 25g's deceleration is $25 \times 400 = 10,000$ lbf, for a safety factor of: $\frac{48,000}{10,000} = 4.8$.

Under the same load conditions, the legs are subjected to a shear stress between the mounting flange and the gusset end. Assuming this load is carried by the cross section of the leg, the area in shear is: $A = \frac{3}{8}" \times 2\frac{5}{8}" = \frac{63}{64}$ sq in. The load per leg at 25g's is $\frac{10,000}{4} = 2500$ lbf.

The stress per leg = $\frac{2500}{\frac{63}{64}} = 2540$ psi.

The material is 2024-T851, with a shear strength of 43,000 psi, giving a safety factor of $\frac{43,000}{2540} = 17$.

2.

The shear strength of the complete leg, including the top and bottom gussets, has been calculated using the complete parabolic "uniform strength" beam formula. (Page 5-49, Std. Hdbk. for Mech. Eng., 7th Ed., Mc-Graw-Hill)

The parabolic gusset shape, shown in Fig 1, falls within the designed gusset shape -

$$S_s = \frac{6 W l}{b h^2}$$

where S_s = maximum shear stress

W = load (2500 lbf)

l = length (3 1/4 in)

b = thickness (1/4")

h = parabolic height (4 1/2")

$$S_s = \frac{6 \times 2500 \times 3.25}{.25 \times 4.5^2} = 9630 \text{ psi.}$$

$$S.F. = \frac{43000}{9630} = 4.5$$

The bending moment which will produce elastic lateral buckling is given by (Page 448, Design Analysis of Shafts and Beams, Hopkins, Mc-Graw-Hill)

$$M' = \frac{\pi b^3 \sqrt{E G} (H - R')}{6 l \log \left(\frac{H}{R'} \right)}$$

where $H = \text{gusset height } (6\frac{1}{2}")$
 $h' = \text{gusset height } (\frac{7}{8}")$
 $E = 10.6 \times 10^6 \text{ psi}$
 $G = 3.75 \times 10^6 \text{ psi}$

$$M' = \frac{\pi \times .25^3 \sqrt{10.6 \times 10^6 \times 3.75 \times 10^6} (6.5 - .875)}{6 \times 3.25 \log \frac{6.5}{.875}} = 102,500 \text{ in lb}$$

The bending moment which each leg will see under 2500 lbs will be

$$M = Wl = 2500 \times 3.25 = 8,125 \text{ in lb}$$

The safety factor from a buckling standpoint is then:

$$S.F. = \frac{M'}{M} = \frac{102,500}{8,125} = 12.6$$

Important: These instructions are for individual cells. If cells are to be assembled into a battery pack contact the manufacturer for proper instructions, indicating the number of cells, voltage, capacity rating and discharge currents of the pack.

APPENDIX VIII

BULLETIN: 1000 SERIES SERVICE AND OPERATING INSTRUCTIONS FOR THE YARDNEY SILVERCEL[®] BATTERY

MODEL: HR4DC-1
CONDITION: DC



EFFECTIVE DATE: January, 1971

NOTE: Unless otherwise indicated, these instructions shall supersede earlier dated information.

YARDNEY ELECTRIC DIVISION

Pioneers in Compact Power[®]

82 MECHANIC STREET, PAWCATUCK, CONN. 02891

1. INTRODUCTION

Here is your Yardney Compact Power battery designed to meet your exact requirements. It is efficient and reliable. Rugged, yet light in weight. Powerful, yet sensitive.

Before proceeding to service and operate your battery, read this entire manual in order to learn how to maintain it properly for maximum life and performance.

2. DESCRIPTION

The YARDNEY SILVERCEL is a silver/zinc alkaline battery which differs considerably from the more familiar lead/acid battery, and to a certain extent from other alkaline batteries such as nickel/cadmium, nickel/iron, etc. Silver and zinc are employed as the electrodes. The electrolyte is a strong solution of potassium hydroxide (KOH). The techniques for servicing the YARDNEY SILVERCEL are quite simple and should be followed closely.

3. AVAILABLE CELL TYPES

The YARDNEY ELECTRIC CORPORATION manufactures three series of SILVERCEL batteries:

- (a) HR (Hi Rate Discharge) series - for applications requiring the total energy of a cell to be expended in one hour or less. The life expectancy of HR batteries is approximately 10 to 20 charge-discharge cycles or a period averaging 6 months wet life, whichever comes first.
- (b) LR (Low Rate Discharge) series - for applications requiring the total energy of a cell to be expended over a period of time greater than one hour. The life expectancy of LR batteries is approximately 60 to 100 charge-discharge cycles or a period averaging 9 to 12 months wet life, whichever comes first.
- (c) PM Series (Manually Activated Primary Batteries) - for applications requiring quick activation and high-rate discharges. The life expectancy of PM SILVERCEL batteries is approximately either 3 to 5 cycles or a period of 2 months wet life, whichever comes first.

4. EXPANSION CHARACTERISTIC

- (a) Subsequent to filling, the YARDNEY SILVERCEL may evidence swelling perpendicular to the electrode face. The swelling may cause difficulties in subsequent cell packaging; if excessive, may also impair cell performance, and sometimes cell cases may crack.
- (b) To avoid swelling, the cells should be restrained before filling and kept restrained at all times, as explained in paragraphs (c) and (d).
- (c) If cells are to be assembled into a battery container where there is no room for swelling, said assembly should be done before filling. If this is not possible, proceed as indicated below.

- (d) For cells that are not to be assembled into a container designed to prevent swelling, or when assembly prior to filling is impossible, restrain by (A) stacking the cells side by side, (B) adding a wooden or metal plate (at least 1/2 inch thick) to both ends of the row of cells and (C) restraining with clamps which are hand tighten to the cell group dimension. These clamps should not be removed until just before assembly.

For permanent restraining outside of any container, use metal straps instead of a clamp.

NOTE: Avoid excessive pressure on the cells when clamping or strapping. This may crack the cell cases.

5. SHORT CIRCUITS

The YARDNEY SILVERCEL battery is capable of supplying unusually high current. However, a prolonged short-circuit may destroy the battery. To avoid short-circuits all tools used in servicing should be properly insulated with electrical tape or varnish.

6. Critical Temperatures

Low temperatures (as low as -55°F.) will not permanently damage the SILVERCEL, and warming it will restore its capacity. High temperatures are definitely harmful. The plastic case begins to soften at 185°F. (85°C.). Do not store the SILVERCEL for prolonged periods at temperatures higher than 110°F.

7. Peroxide Portion of Discharge Curve

A characteristic of the SILVERCEL, predominantly when discharged at the one hour rate or lower, is the "peroxide" portion of the discharge curve. This characteristic occurs at the beginning of a discharge and is evidenced by a high initial voltage which gradually decreases to a steady value and is present for approximately 15-25 per cent of the normal discharge curve. The elimination of this sloping voltage, if undesirable, can be accomplished by pre-discharging the SILVERCEL at approximately two and one-half times the one hour rate for a minute or two. The higher the discharge rate the less noticeable is the "peroxide" characteristic.

8. Gas Evolution

The YARDNEY SILVERCEL is relatively free from the hydrogen explosion hazard which is common to conventional types of batteries when used in closed, non-ventilated areas. However, sufficient hydrogen to cause an explosion (if ignited) may be generated should the SILVERCEL become defective or is badly overcharged.

No special battery room is required for servicing Yardney SILVERCEL batteries. Just allow for adequate work space, light and ventilation.

9. Terminology

1. Battery — The term "battery" is used to refer to both battery and cell. Occasionally "cell" is used to differentiate between the basic unit and the battery.
2. Nominal Capacity — The term nominal capacity refers to the capacity classification of the battery. For most batteries, nominal capacity closely approximates working capacity toward the end of battery life.
3. Cycle — The term cycle includes both a charge and discharge.
4. Charging end voltage — The charging end voltage indicates the charging voltage not to be exceeded while the battery is on charge.
5. Plateau — The term plateau applies to the flat portion of the discharge curve and is used to indicate the steady voltage prevalent during most of the discharge.

PRECAUTIONS FOR HANDLING FILLED BATTERIES

Ordinarily, no trace of the alkaline electrolyte (potassium hydroxide) appears on the outside of the case of filled batteries. However, personnel who work with the batteries should wash their hands thoroughly after handling them.

If potassium hydroxide is accidentally spilled it can be readily neutralized and washed away. Read the instructions below for proper handling of the electrolyte.

Personnel who fill the batteries or otherwise handle the electrolyte should read the precautions outlined below to assure maximum safety and prevent injury which may result from accidental spillage of electrolyte.

PRECAUTIONS FOR HANDLING ELECTROLYTE

1. General Comments:

The electrolyte (a strong solution of potassium hydroxide) is alkaline and corrosive. It should be handled with care. If neglected, the electrolyte will cause serious burns when it is permitted to come in contact with the eyes or skin. Alkali-proof apron, rubber gloves and splash-proof goggles or a face mask are recommended for personnel engaged in the filling of SILVERCEL batteries.

2. Antidotes, Internal:

Give large quantities of water and a weak acid solution such as: vinegar, lemon juice, or orange juice. Follow with one of the following: white-of-egg, olive oil, starch water, mineral oil, or melted butter. Obtain medical attention at once.

3. Antidotes, External:

- (a) For the skin: wash the affected area with large quantities of water. Neutralize with vinegar, lemon juice, or 5% acetic acid, and wash with water. Obtain medical attention at once.
- (b) For the eyes: flush thoroughly with water. Follow with saturated solution of boric acid. Use this first-aid treatment until medical aid can be summoned.

4. Washing Glassware:

The electrolyte is somewhat corrosive to glass. All beakers and syringes should be thoroughly washed with water following their use.

5. Carbon Dioxide Absorption:

Store the electrolyte in closed alkali resistant containers as it absorbs carbon dioxide from the air. Prolonged exposure to the air will impair the properties of the electrolyte.

6. Caution:

Do not, under any circumstance, attempt to use any type of electrolyte other than the special electrolyte furnished with the YARDNEY SILVERCEL. Other types of electrolyte will destroy it.

For best soaking results, the temperature of the electrolyte at the time of filling should be maintained at 70°F - 80°F.

FILLING AND FORMATION PROCEDURE FOR *Yardney* SILVERCEL BATTERIES

1. The Yardney SILVERCEL batteries are shipped with sufficient electrolyte in separate containers to activate them, and with a filling kit containing the following items:

NOTE: Batteries not to be used within 30 days of receipt, should be stored in dry condition.

Item	Quantity	Description
1	24-1	oz. polyethylene bottles (with caps), each containing sufficient amount of electrolyte to activate one cell of the battery.
2	5	Extra vent caps
3	5	Extra sponge rubber plugs
4	25	Vent cleaners
5	1 pair	Tweezers
6	¼ oz.	Absorbent cotton
7	1	Polyethylene filling caps

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2. To properly fill each cell, proceed as follows:

- (a) Remove the plastic vent cap from each cell. With tweezers, remove the sponge rubber plug from the vent hole. Keep both the vent cap and the sponge rubber plug.
- (b) Remove the plastic cap from an electrolyte bottle containing the proper amount of electrolyte for one cell. Puncture the polyethylene seal with the tweezers (provided in the filling kit) or other sharp object.
- (c) Screw one of the polyethylene filling caps, provided in the filling kit, securely onto the electrolyte bottle.
- (d) Insert the filling cap tip into the cell vent hole, twisting clockwise to insure a tight fit.
- (e) Squeeze the electrolyte bottle gently, maintaining the pressure for a few seconds to avoid drawing back electrolyte into the bottle. Repeat this operation slowly until *all* of the electrolyte has been transferred into the cell. If the electrolyte is repeatedly drawn back into the bottle, wait for a few minutes until the level in the cell decreases, then introduce the remaining electrolyte into the cell.
- (f) After filling is completed, remove any excess electrolyte from the vent hole by using the vent cleaner. Insert a vent cleaner up to the knot, into the cell vent hole and turn for one complete revolution. Use new vent cleaner for each cell.
- (g) Remove any excess electrolyte from around the outside of the vent holes with a piece of cotton, using tweezers.
- (h) Replace the sponge rubber plug into the cell vent hole after the removal of excess electrolyte is completed. *It is recommended that the sponge rubber plug be positioned in the cell vent immediately after the filling of each cell in order to minimize any possibility of filling one cell twice or not filling a cell at all.*
- (i) After the filling operation of one cell has been completed, the polyethylene filling cap should be removed from the bottle, the filling bottle discarded and the filling cap should be put on a new electrolyte bottle.
- (j) After filling all cells in the same manner as described above and having replaced the sponge rubber plugs, allow the battery to soak for the prescribed period (Item 4, 1009). During the soaking period the battery should be tilted approximately 30 degrees from the vertical in the plane parallel to the battery plates. Secure the battery in this position and allow the battery to soak for half of the prescribed soaking time. Tilt the battery on its opposite side for the remainder of the soaking period.

NOTE: The cell vent caps should not be replaced until battery formation (Sec. 3 and 4) is completed.



3. Activation of the Dry Charged Battery

- (a) After the addition of electrolyte and the elapse of the prescribed soaking time (page 1009, item 4) the battery is ready for use. No formation cycling is necessary with the dry charged battery.
- (b) Before using the battery, open circuit voltages should be checked on each cell. This voltage should be approximately 1.82 - 1.86 volts per cell immediately following the prescribed soaking time. However, the open circuit voltage may not remain completely stable for a period of 48 hours immediately following the prescribed soaking period.

NOTE: The open circuit voltage of PM type Silvercels may be anywhere in the range of 1.60 - 1.86 volts after initial filling. This is because the positive plates are processed to remove the "Peroxide Voltage" on initial discharge (in many models). However, after the first recharge, the open circuit voltage should be in the range of 1.82 - 1.86 volts/cell.

4. Initial Discharge and Drain

Following its initial discharge, drain the battery further at the 10 hour discharge rate (nominal rated capacity divided by 10) until the battery voltage drops to 1.0 volts per cell (for batteries - 1.0 volts x number of cells).

NOTE: This drain is necessary after the initial discharge and after every five or six application discharges to assure maximum life for the battery. To recharge, see "OPERATIONAL PROCEDURES", page 1006.

5. Storage of Dry Charged Battery

(a) Storage prior to filling:

If it is anticipated that the battery will not be used for a prolonged period of time following its receipt it should be stored in the dry state for optimum results. When it is desired to use the battery it can be filled as described in "FILLING & FORMATION PROCEDURE", page 1004, soaked the proper amount of time and used.

(b) Storage Subsequent to filling:

If it is desired to store the battery for thirty days or longer at some time after the battery has been filled it should be stored in the discharged condition following the storage instructions as outlined in "MAINTENANCE" section, page 1007, paragraph 3.

6. Use Subsequent to Activation

If the battery is to be used within thirty days following activation, follow the instructions as outlined in "OPERATIONAL PROCEDURES", page 1006.



1. Battery Rating

The nominal capacity of this battery is given on page 1009, item 1; and the nominal voltage is given in item 2.

2. Intercell Connection

Periodically and before a high rate discharge is performed, a check on the tightness of the cells top terminal nuts is recommended to assure maximum intercell conductivity. Tighten the top terminal nuts to the correct torque (item 16.) Bottom nuts located at the base of the terminal post are preset and should *not* be tightened or loosened.

3. Subsequent Charging

Charging can be accomplished by either the modified constant potential or the constant current method. While the constant current method provides the fastest means of achieving a normal input, the modified constant potential method requires much less personal attention and can be obtained automatically by considerably less complex equipment.

ALL AUTOMATIC YARDNEY SILVERCEL CHARGERS ARE DESIGNED TO CHARGE BY THE MODIFIED CONSTANT POTENTIAL METHOD (Tapered charging). These instructions give values for both modified constant potential and constant current charges.

Initiate charging the battery at the rate specified (item 11a or 11b) until the battery voltage reaches the end charging voltage, (Item 12) while charging. For constant current charging, maintain the rate throughout the charge. For modified constant potential charging no further current adjustment is necessary during the charge.

4. Charging Temperature

A battery should be a temperature of 60°F to 80°F before charging.

5. Charging Precautions

- (a) The battery voltage during any charge should never be allowed to exceed the end voltage (item 12) while charging. An adequate ampere-hour input is normally obtained at this point. If charging is not stopped, the voltage rises rapidly and may cause excessive heating and gassing, detrimentally affecting the battery.
- (b) Charging shall be interrupted for 8 to 16 hours, if at any time during the charge, electrolyte is forced out of the cell vent, or the intercell connectors or terminals become too warm to touch (140°F to 150°F).

NOTE: Be sure the hole in the vent cap (or valve) is clear.

6. Discharge Rates

- (a) HR and PM (High Rate Discharge) Batteries:
 - 1. HR batteries are designed for unusually high discharge rates. For optimum battery operation and maximum battery life we recommend that the time limit specified for continuous discharge in items 13 (HR), 14 and 15 be observed.

2. If it should be desired to discharge the battery at a higher rate than the maximum recommended rate, or for a longer time, care should be taken not to allow the battery to heat itself during the discharge beyond 165°F. (temperature measured on either cell terminal by using a thermocouple) if reliability of recyclability is desired. After the discharge is concluded, the cell's plastic container will continue to heat because of the thermal lag.

(b) LR (Low Rate Discharge) Batteries:

If maximum capacity and recyclability are desired, LR batteries should be discharged at a rate not to exceed that shown in item 13 (LR) (Page 1009).

1. GENERAL

A minimum of maintenance is required to keep the SILVERCEL in optimum operating condition. Cell tops and terminals should be kept clean and dry (any corrosion due to atmospheric conditions should be removed immediately). Also, an occasional inspection of the vent cap and sponge rubber plug (or vent screw valve) should be made to assure that they are not clogged.

2. BATTERY SERVICEABILITY CHECK

Whenever circumstances permit, an open circuit voltage check (no load being applied to the battery) should be made 24 hours after the battery has been fully charged. If the open circuit cell voltage is observed to be less than 1.82 volts during this inspection, check the following items:

- (a) Check voltmeter accuracy with a known reference voltage.
- (b) Observe the top surface of the battery to see if it is deformed from overheating or is gassing excessively. If this is the case, the battery should be considered defective and removed from service.
- (c) If the battery does not appear to be defective, charge it according to "OPERATIONAL PROCEDURE" (Page 1006) and again check the open-circuit voltage after an additional 24 hour stand period. A cell should be considered unserviceable if the voltage again reads below 1.82 volts.

3. STORAGE CONDITIONS

(a) Dry Batteries:

It is recommended that batteries shipped in the dry condition, which will not be placed in service for 30 days or more, should be stored in the dry condition at a temperature not to exceed 90°F.

Dry, uncharged batteries may be stored for several years.

Dry, charged batteries may be stored for periods up to three years, depending upon the temperature at which they are stored. For best results, store at low temperature, in a dark room.

(b) Wet Batteries:

If it is desired to store the battery for 30 days or longer, it should be discharged at low rate (3 hour rate or lower) to 1.0 volt per cell (for batteries - 1.0 volt x number of cells). Then tape all cell vent caps with cellophane tape and apply a thick coating of vaseline, or equal, to the top surface of cells including terminals and taped areas. Cells having vent screw valves do not require taping or coating with vaseline.

The battery may be stored safely at temperatures between 0°F to 110°F. However, the lower temperature ranges (0° to 70°F) are more satisfactory for storage with the optimum temperature for long term storage being 32°F.

NOTES (1): It is important that the battery not be stored in an atmosphere heavy in carbon dioxide gas.

(2): The restraining provisions mentioned in page 1001 are fully applicable to wet storage of cells.

4. BOOSTER CHARGE

To insure optimum performance, after an extended charged stand period, the battery should be given a freshening charge before it is used. Charge at the recommended rate (item 11a or 11b, page 1009) until the battery voltage reaches the prescribed value (item 12) while charging. (The freshening charge should take approximately one hour or less.)

5. Occasional Drain

To assure the maximum number of cycles for the life of the battery, drain-discharge it after every 5 or 6 application discharges. This drain can be accomplished at the 10-hour discharge rate (nominal rated capacity divided by 10) until the voltage drops to 1.0 volt per cell (for batteries - 1.0 volt x number of cells). To recharge, see "OPERATIONAL PROCEDURES," page 1006.

6. Correct Electrolyte Level

The electrolyte level should never be permitted to exceed the height of the plates, except during the initial filling of each cell. The battery contains sufficient electrolyte and no additional electrolyte or distilled water should normally be added through-out the life of the battery. However, if the battery, when fully charged *and inspected immediately after charge*, shows no electrolyte, *distilled water* should be added by means of a hypodermic syringe or filling bottle until the level reaches one half (1/2) of the plate height. When adding distilled water, allow sufficient time to elapse (15 to 20 minutes) so that the electrolyte level has an opportunity to equalize itself. Care should be taken not to puncture or cut the separator material located below the cell vent trap.

NOTE: Where cell cases are not transparent do not attempt to adjust electrolyte level under any conditions.

7. Recommended Cleaning Solutions

Cell tops and terminals can be effectively cleaned with a 4% solution of glacial acetic acid.

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SERVICE AND OPERATING DATA FOR THE YARDNEY SILVERCEL®

BATTERY MODEL NO. HR40C-1

ITEM	DESCRIPTION		UNITS										
	Nominal Characteristics												
1	Capacity	4.0	AH										
2	Voltage (1.5 volts x number of cells)	1.5	Volts										
	Filling and Soaking												
3	Electrolyte Quantity (per cell)	14	cc										
4	Minimum Soaking Time	48	Hr s.										
	Formation Charge(s)												
5a	Charging Rate (Method "a" Constant Current)	NA	Amps										
5b	Initial Charging Rate (Method "b" Modified Constant Potential)		Amps										
6	Charging End Voltage (2.0 volts x number of cells measured across battery terminals during charging).		Volts										
	Formation Discharge(s)												
7	Discharge Rate	NA	Amps										
8	End Voltage (1.1 volts x number of cells)		Volts										
9	Minimum Discharge Time		Mins.										
10	Minimum Output		AH										
	Subsequent Charges												
11a	Charging Rate (Method "a" Constant Current)	0.50	Amps										
11b	Initial Charging Rate (Method "b" Modified Constant Potential)	1.25	Amps										
12	Charging End Voltage (2.0 volts x number of cells measured across battery terminals during charging.)	2.05	Volts										
	Service Discharges												
	A. <u>HR and PM (high rate) Series</u>												
	Time limits at various discharge rates												
	<table><tr><th>Discharge Rate (Amps)</th><th>Time Limit (Minutes)</th></tr><tr><td>4.0</td><td>60</td></tr><tr><td>12.0</td><td>20</td></tr><tr><td>24.0</td><td>10</td></tr><tr><td>32.0</td><td>5</td></tr></table>	Discharge Rate (Amps)	Time Limit (Minutes)	4.0	60	12.0	20	24.0	10	32.0	5		
Discharge Rate (Amps)	Time Limit (Minutes)												
4.0	60												
12.0	20												
24.0	10												
32.0	5												
13													
14													
15													
	B. <u>LR (low rate) Series</u>												
13	Maximum Discharge Rate	NA	Amps										
	End Voltage		Volts										
	Battery Assembly Data												
16	Torque (Top Terminal Nuts)	6-10	In. -Lb										



YARDNEY ELECTRIC CORP.

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1009

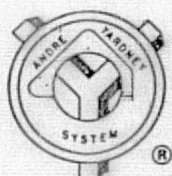
REV. 5-60

EXPLANATORY NOTE TO GENERAL DATA FOR STANDARD YARDNEY SILVERCEL[®] BATTERIES

ITEM	TITLE	UNITS	DESCRIPTION
1	Nominal Capacity	AH	Indicates capacity class of the cell. For most cell models working cell capacity toward the end of cell life closely approximates nominal capacity.
2	Nominal Voltage	Volts	Indicates voltage class of the cell. For most cell models, nominal voltage closely approximates closed-circuit voltage at the 1 hour-rate.
3	Electrolyte Quantity	CC	Indicates the amount of electrolyte to be used in filling.
4	Minimum Soaking Time	Hrs.	Indicates minimum length of time the cell should be allowed to soak between filling and formation.
5a	Charging Rate	Amps	Indicates charging current for cell formation, using constant current charging method.
5b	Initial Charging Rate	Amps	Indicates initial charging current for cell formation not to be exceeded, using modified constant potential charging method.
6	Charging End Voltage	Volts	Indicates charging voltage not to be exceeded while cell is on charge.
7	Discharge Rate	Amps	Indicates discharge rate to be used during cell formation period.
8	End Voltage	Volts	Indicates closed circuit voltage at which formation discharge should be stopped.
9	Minimum Discharge Time	Mins.	Indicates minimum length of time the cell should be capable of sustaining the discharge before its voltage drops to 1.1 volt when discharged at the rate, item 7, in order to be regarded fully formed.
10	Minimum Output	AH	Indicates the AH output corresponding to item 9.
11a	Charging Rate	Amps	Indicates charging current in subsequent service, using constant current charging method.
11b	Initial Charging Rate	Amps	Indicates initial charging current in subsequent service, using modified constant potential charging method.
12	Charging End Voltage	Volts	Indicates charging voltage not to be exceeded while cell is on charge.
13 thru 15	Service Discharges		Indicates, for continuous (non-intermittent) discharges at various currents, the length of discharge time not to be exceeded for safe operation and maximum cell life.
16	Battery Assembly Data	In-Lb.	Indicates the torque not to be exceeded in tightening cell terminal top nuts when assembling individual cells to form a battery pack.

NOTES: 1. All data shown apply to individual cells only (not battery packs).

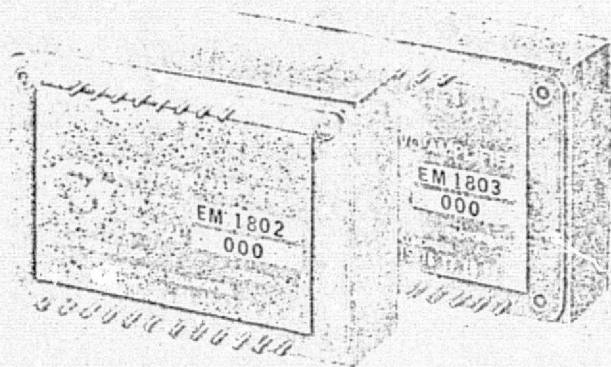
2. All data are applicable to initial cell temperatures in the range of 60-90° F. only.



YARDNEY ELECTRIC CORP.

Patents granted and pending.

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MODEL EM-1802
200 WATT
MODEL EM-1803
300 WATT
DC SERVO AMPLIFIERS
MIL SPEC DESIGN

EM-1802 **EM-1803**
\$275 **\$375**
(1-10 units) (1-10 units)
significant quantity discounts

APPLICATIONS

- DC Torque Motors
- Other DC Servo Motors
- Deflection Coils
- Servo Valves

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FEATURES

SMALL SIZE for packaging flexibility / WIDE BANDWIDTH for fast servo response / VOLTAGE OR CURRENT FEEDBACK to provide low or high impedance output / ADJUSTABLE GAIN for maximum flexibility / CURRENT LIMITING to prevent demagnetization of a DC torque motor and for short circuit protection.

DESCRIPTION

The EM-1802 and EM-1803 are small (3" x 2" x 1") encapsulated power amplifiers used to drive DC servo motors. Their outputs range up to 200 and 300 watts respectively. The amplifiers are particularly well suited for driving DC torque motors by virtue of their wide bandwidth and adjustable current limiting features. They can be utilized as voltage or current amplifiers by terminal selection and their gain can be varied by the addition of external resistors.

The amplifiers are designed to be mounted on an external heat sink. All electrical connections are made at pin terminals. The EM-1802 and EM-1803

have been designed to meet MIL-E-5400 including MIL-STD-704. For further information regarding MTBF, qualification testing, etc., consult the factory.

HOW THEY WORK

In the diagram below, the basic elements of the EM-1802 and EM-1803 are shown.

The EM-1802 and EM-1803 each consists of a high gain, wide bandwidth, differential amplifier driving a power amplifier. This in turn drives an output bridge consisting of 4 NPN power transistors. The difference between the two amplifiers is that the EM-1803 contains higher power output transistors.

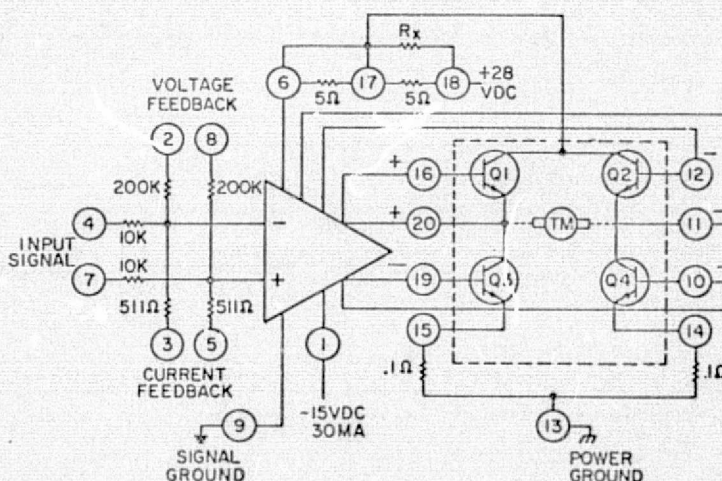
Connecting internal voltage or current feedback resistors to the appropriate output sensing terminals results in either a voltage or current amplifier.

A current limiting amplifier senses and damps load current during motor plugging, thus protecting the motor against demagnetization. This also provides short circuit protection. A power sharing amplifier* assures approximately equal dissipation in the upper and lower output bridge transistors.

Primary power is drawn from a +28 volt DC supply (MIL-STD-704 is met). In addition a -15 volt, 30 ma bias supply is required.

MODE	CONNECT	
VOLTAGE FEEDBACK	2 & 20	8 & 11
CURRENT FEEDBACK	3 & 14	5 & 15

CURRENT LIMIT SET		
EM-1802 EM-1803 W/BIDGE	$R_x = \frac{2}{I_{CL} \cdot 4}$	SHORT 6 TO 17



EM-1802 (200 WATTS) - EM-1803 (300 WATTS) CONFIGURATION

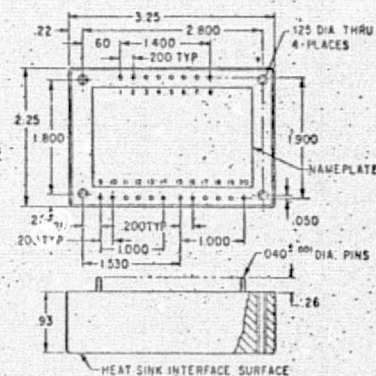
SPECIFICATIONS (Nominal)

EM-1802

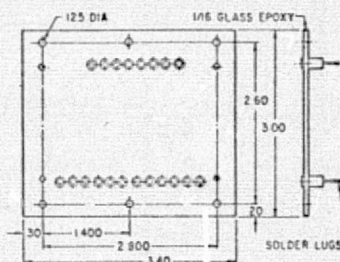
EM-1803

Output Power Max.:		
Case at 25°C	200 watts	300 watts
Case at 90°C	100 watts	200 watts
Output Voltage (B+ at 28 volts)	±20 volts DC	±20 volts DC
Output Current Max. (Case at 90°C)	±5 amps	±10 amps
Output Current Limit Adj. Range	1 amp to 10 amps	1 amp to 15 amps
Dynamic Output Impedance	0.1 ohm	0.1 ohm
Input Impedance	10,000 ohms	10,000 ohms
Frequency Response		
Small Signal	10,000 Hz	10,000 Hz
Full Output	1,000 Hz	1,000 Hz
Gain (Adjustable):		
Voltage Amplifier	20v/v	20v/v
Current Amplifier	0.5a/v	0.5a/v
Drift (ref. to input)	10μv/°C	10μv/°C
DC Dead Band (ref. to input)	±50μv	±50μv
Positive Supply Voltage	+20 to +32 vdc (MIL-STD-704 applies)	+20 to +32 vdc (MIL-STD-704 applies)
Positive Supply Quiescent Current	0.05 amp	0.05 amp
Negative Bias Supply Voltage	-15 ±2 volts	-15 ±2 volts
Negative Bias Supply Current	0.03 amp	0.03 amp
Weight	10 oz	10 oz

OUTLINE DIMENSIONS



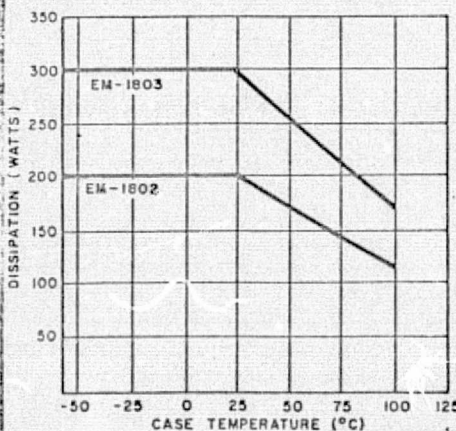
OPTIONAL MATING SOCKET



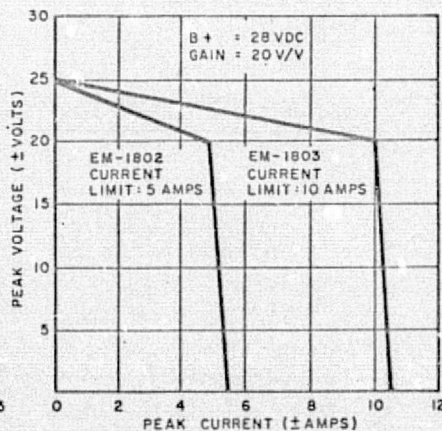
SOCKET PRICE
\$10.00 (1-10 UNITS)

TYPICAL PERFORMANCE CURVES

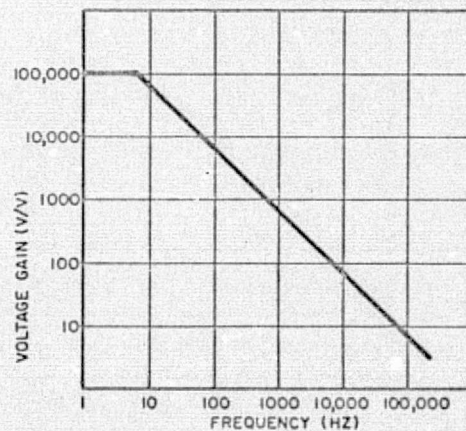
TEMPERATURE DERATING



OUTPUT SWING



OPEN LOOP FREQUENCY RESPONSE



80

XR-2240/2340

APPENDIX X

Programmable Timer/Counter

NOVEMBER 1973

PROGRAMMABLE TIMER/COUNTER

The XR-2240 Programmable Timer/Counter is a monolithic controller capable of producing ultra-long time delays without sacrificing accuracy. In most applications, it provides a direct replacement for mechanical or electromechanical timing devices and generates programmable time delays from micro-seconds up to five days. Two timing circuits can be cascaded to generate time delays up to three years.

As shown in Figure 1, the circuit is comprised of an internal time-base oscillator, a programmable 8-bit counter and a control flip-flop. The time delay is set by an external R-C network and can be programmed to any value from 1 RC to 255 RC.

In astable operation, the circuit can generate 256 separate frequencies or pulse-patterns from a single RC setting and can be synchronized with external clock signals. Both the control inputs and the outputs are compatible with TTL and DTL logic levels.

FEATURES

- Timing from micro-seconds to days
- Programmable delays: 1 RC to 255 RC
- Wide supply range: 4V to 15V
- TTL and DTL compatible outputs
- High accuracy: 0.5%
- Excellent temp. stability: 40 ppm/°C
- External Sync and Modulation Capability
- Excellent Supply Rejection: 0.05%/V

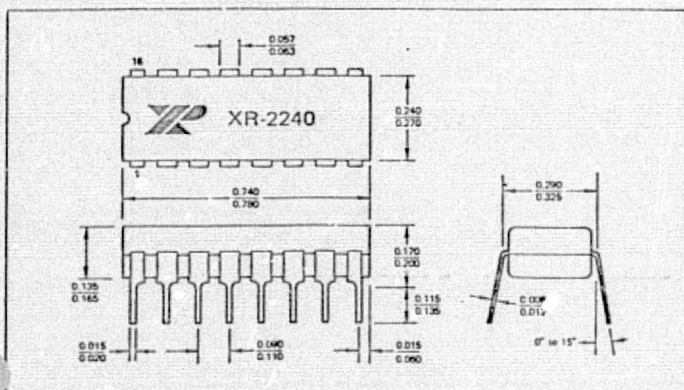
ABSOLUTE MAXIMUM RATINGS

Supply Voltage	18V
Power Dissipation	750 mW
Derate above +25°C	5 mW/°C
Operating Temperature	
XR-2240M	-55°C to +125°C
XR-2240/2340	0°C to +75°C
Storage Temperature	-65°C to +150°C

APPLICATIONS

- Precision Timing
- Long Delay Generation
- Sequential Timing
- Binary Pattern Generation
- Frequency Synthesis
- Pulse Counting/Summing
- A/D Conversion
- Digital Sample and Hold

PACKAGE INFORMATION



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FUNCTIONAL BLOCK DIAGRAM

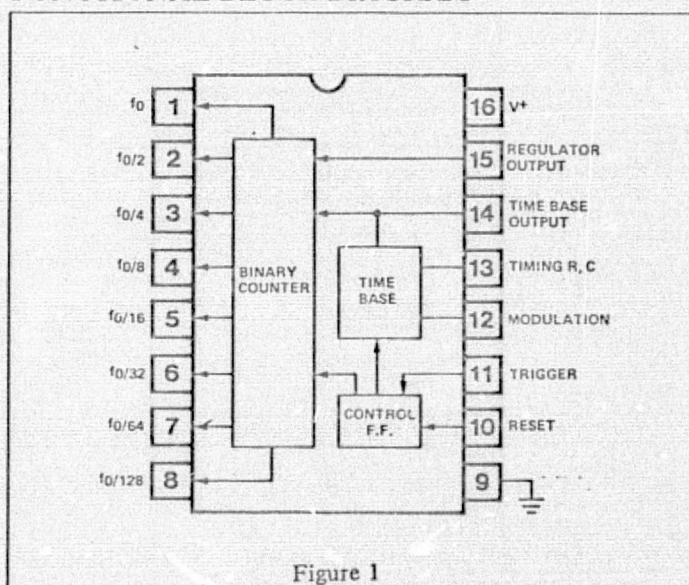


Figure 1

EXAR INTEGRATED SYSTEMS, INC.

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ELECTRICAL CHARACTERISTICS

Test Conditions: See Figure 2, $V^+ = 5V$, $T_A = 25^\circ C$, $R = 10\text{ k}\Omega$, $C = 0.02\text{ }\mu F$, unless otherwise noted.

PARAMETERS	XR-2240			XR-2340			UNIT	CONDITIONS
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
GENERAL CHARACTERISTICS								
Supply Voltage	4		15	4		15	V	For $V^+ < 4.5V$, Short Pin 15 to Pin 16
Supply Current								
Total Circuit		3.5	6		4	7	mA	$V^+ = 5V$, $V_{TR} = 0$, $V_{RS} = 5V$
Counter Only		12	16		13	18	mA	$V^+ = 15V$, $V_{TR} = 0$, $V_{RS} = 5V$
		1			1.5		mA	See Figure 3
Regulator Output, V_R	4.1	4.4		3.9	4.4		V	Measured at Pin 15, $V^+ = 5V$
	6.0	6.3	6.6	5.8	6.3	6.8	V	$V^+ = 15V$, See Figure 4
TIME BASE SECTION								See Figure 2
Timing Accuracy *		0.5	2.0		0.5	5	%	$R = 10\text{ k}\Omega$, $C = 0.02\text{ }\mu F$, $V_{RS} = 0$, $V_{TR} = 5V$
Temperature Drift		40	150		50		ppm/ $^{\circ}C$	$0^{\circ}C \leq T \leq 75^{\circ}C$
Supply Drift		0.05	0.2		0.08	0.3	%/V	
Max. Frequency	100	200		100	200		kHz	$R = 1\text{ k}\Omega$, $C = 0.005\text{ }\mu F$
Modulation Voltage Level								Measured at Pin 12
	3.00	3.50	4.0	2.80	3.50	4.20	V	$V^+ = 5V$
		10.5			10.5		V	$V^+ = 15V$
Recommended Range of Timing Components								See Figure 8
Timing Resistor, R	0.001		10	0.001		10	M Ω	
Timing Capacitor, C	.005		1000	0.005		1000	μF	
TRIGGER/RESET CONTROLS								
Trigger								Measures at Pin 11, $V_{RS} = 0$
Trigger Level		1.4	2.0		1.4	2.0	V	
Trigger Current		8			10		μA	$V_{RS} = 0$, $V_{TR} = 2V$
Impedance		25			25		k Ω	
Response Time **		1			1		$\mu sec.$	
Reset								
Reset Level		1.4	2.0		1.4	2.0	V	
Reset Current		8			10		μA	$V_{TR} = 0$, $V_{RS} = 2V$
Impedance		25			25		k Ω	
Response Time **		0.8			0.8		$\mu sec.$	
COUNTER SECTION								See Figure 4, $V^+ = 5V$
Max. Toggle Rate	0.8	1.5			1.5		MHz	$V_{RS} = 0$, $V_{TR} = 5V$ Measured at Pin 14
Input:								
Impedance		20			20		k Ω	
Threshold	1.0	1.4		1.0	1.4		V	
Output:								Measured at Pins 1 thru 8
Rise Time		180			180		nsec.	$R_L = 3k$, $C_L = 10\text{ pF}$
Fall Time		180			180		nsec.	
Sink Current	3	5		2	4		mA	$V_{OL} \leq 0.4V$
Leakage Current		0.01	8		0.01	15	μA	$V_{OH} = 15V$

*Timing error solely introduced by XR-2240/2340, measured as % of ideal time-base period of $T = 1.00\text{ RC}$.

**Propagation delay from application of trigger (or reset) input to corresponding state change in counter output at pin 1.

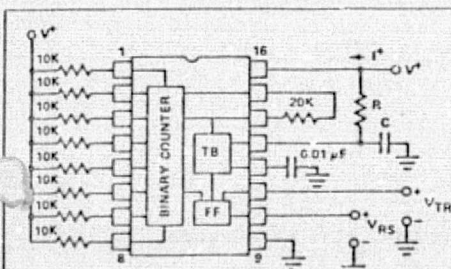


Figure 2. Generalized Test Circuit

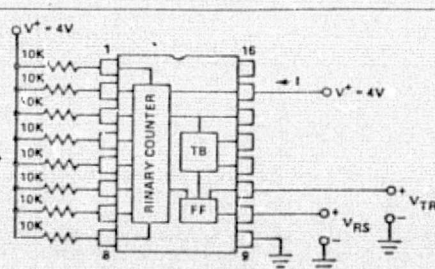


Figure 3. Test Circuit for Low-Power Operation (Time-Base Powered Down)

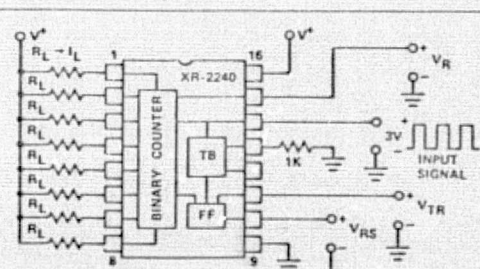


Figure 4. Test Circuit for Counter Section

PRINCIPLE OF OPERATION

The timing cycle for the XR-2240 is initiated by applying a positive-going trigger pulse to pin 11. The trigger input actuates the time-base oscillator, enables the counter section, and sets all the counter outputs to "low" state. The time-base oscillator generates timing pulses with its period, T , equal to $1 RC$. These clock pulses are counted by the binary counter section. The timing cycle is completed when a positive-going reset pulse is applied to pin 10.

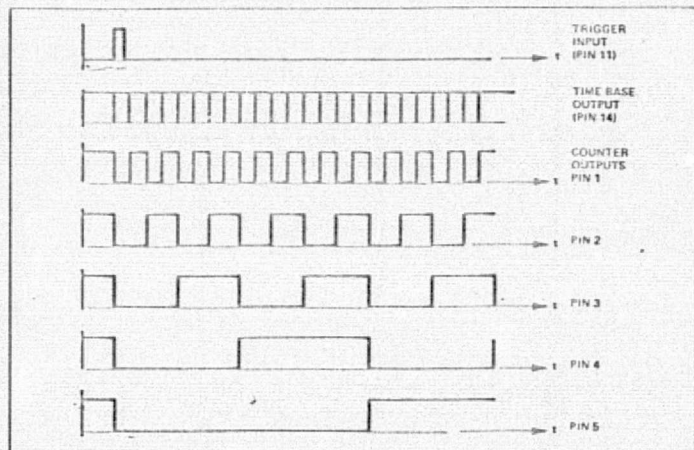


Figure 5. Timing Diagram of Output Waveforms

Figure 5 gives the timing sequence of output waveforms at various circuit terminals, subsequent to a trigger input. When the circuit is at reset state, both the time-base and the counter sections are disabled and all the counter outputs are at "high" state.

In most timing applications, one or more of the counter outputs are connected back to the reset terminal, as shown in Figure 6, with S_1 closed. In this manner, the circuit will start timing when a trigger is applied and will automatically reset itself to complete the timing cycle when a programmed count is completed. If none of the counter outputs are connected back to the reset terminal (switch S_1 open), the circuit would operate in its astable or free-running mode, subsequent to a trigger input.

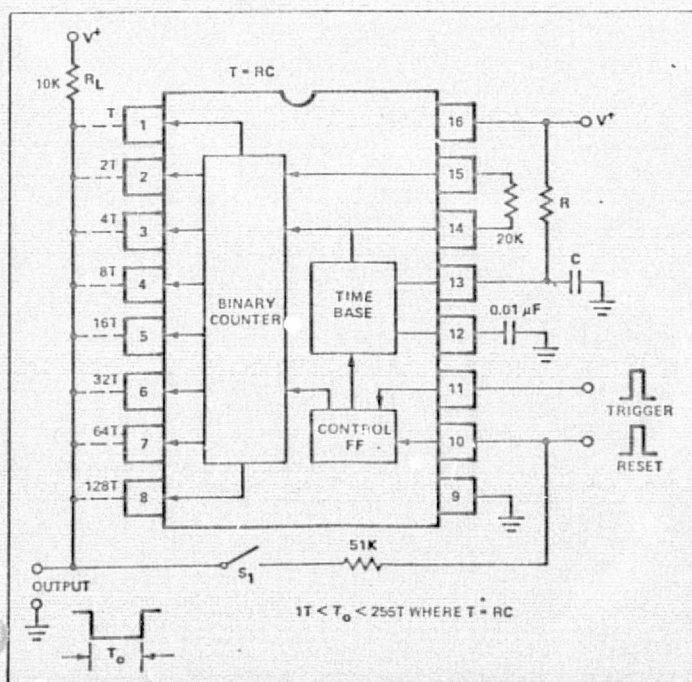


Figure 6. Generalized Circuit Connection for Timing Applications (Switch S_1 Open for Astable Operations, Closed for Monostable Operations)

PROGRAMMING CAPABILITY

The binary counter outputs (pins 1 through 8) are open-collector type stages and can be shorted together to a common pull-up resistor to form a "wired-or" connection. The combined output will be "low" as long as any one of the outputs is low. In this manner, the time delays associated with each counter output can be summed by simply shorting them together to a common output bus as shown in Figure 6. For example, if only pin 6 is connected to the output and the rest left open, the total duration of the timing cycle, T_0 , would be $32T$. Similarly, if pins 1, 5, and 6 were shorted to the output bus, the total time delay would be $T_0 = (1+16+32)T = 49T$. In this manner, by proper choice of counter terminals connected to the output bus, one can program the timing cycle to be: $1T \leq T_0 \leq 255T$, where $T = RC$.

TRIGGER AND RESET CONDITIONS

When power is applied to the XR-2240 with no trigger or reset inputs, the circuit reverts to "reset" state. Once triggered, the circuit is immune to additional trigger inputs, until the timing cycle is completed or a reset input is applied. If both the reset and the trigger controls are activated simultaneously, the circuit reverts to "trigger" state.

DESCRIPTION OF CIRCUIT CONTROLS

COUNTER OUTPUTS (PINS 1 THROUGH 8)

The binary counter outputs are buffered "open-collector" type stages, as shown in Figure 15. Each output is capable of sinking ≈ 5 mA of load current. At reset condition, all the counter outputs are at high or non-conducting state. Subsequent to a trigger input, the outputs change state in accordance with the timing diagram of Figure 5.

The counter outputs can be used individually, or can be connected together in a "wired-or" configuration, as described in the Programming section.

RESET AND TRIGGER INPUTS (PINS 10 AND 11)

The circuit is reset or triggered with positive-going control pulses applied to pins 10 and 11. The threshold level for these controls is approximately two diode drops ($\approx 1.4V$) above ground.

Minimum pulse widths for reset and trigger inputs are shown in Figure 10. Once triggered, the circuit is immune to additional trigger inputs until the end of the timing cycle.

MODULATION AND SYNC INPUT (PIN 12)

The period T of the time-base oscillator can be modulated by applying a dc voltage to this terminal (see Figure 13). The time-base oscillator can be synchronized to an external clock by applying a sync pulse to pin 12, as shown in Figure 16. Recommended sync pulse widths and amplitudes are also given in the figure.

HARMONIC SYNCHRONIZATION

Time-base can be synchronized with integer multiples or harmonics of input sync frequency, by setting the time-base period, T , to be an integer multiple of the sync pulse period, T_s . This can be done by choosing the timing components R and C at pin 13 such that:

$$T = RC = (T_s/m) \text{ where}$$

m is an integer, $1 \leq m \leq 10$.

Figure 17 gives the typical pull-in range for harmonic synchronization, for various values of harmonic modulus, m . For $m < 10$, typical pull-in range is greater than $\pm 4\%$ of time-base frequency.

TYPICAL CHARACTERISTICS.

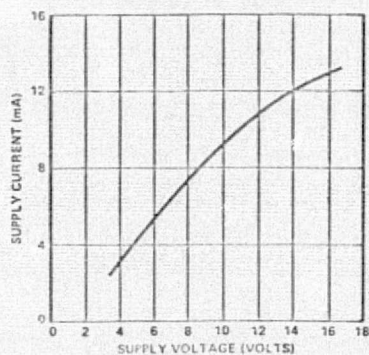


Figure 7. Supply Current vs. Supply Voltage in Reset Condition (Supply Current Under Trigger Condition is ≈ 0.7 mA less)

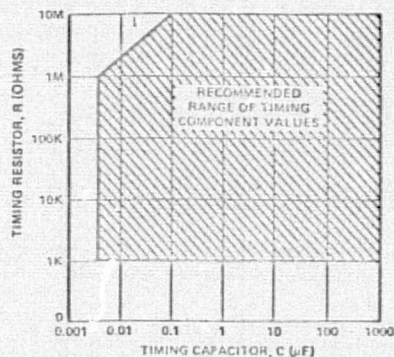


Figure 8. Recommended Range of Timing Component Values

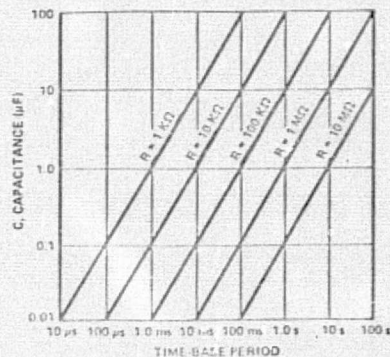


Figure 9. Time-Base Period, T, as a Function of External RC

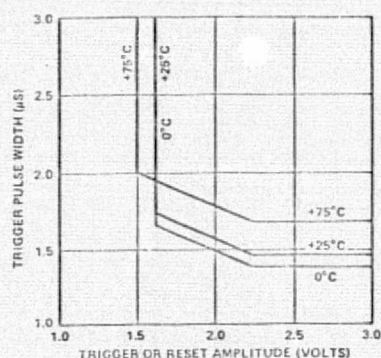


Figure 10. Minimum Trigger and Reset Pulse Widths at Pins 10 and 11

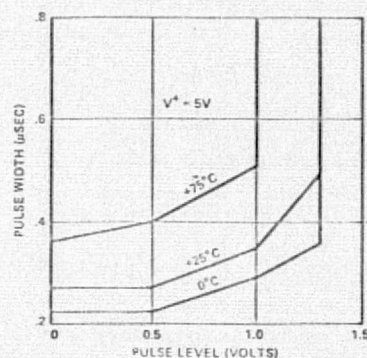


Figure 11. Minimum Counter Trigger Input Level for Operation with External Clock (Measured at Pin 14)

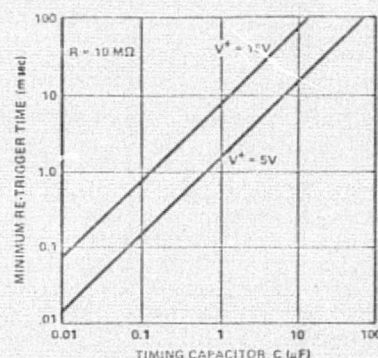


Figure 12. Minimum Re-trigger Time, S, Subsequent to a Reset Input

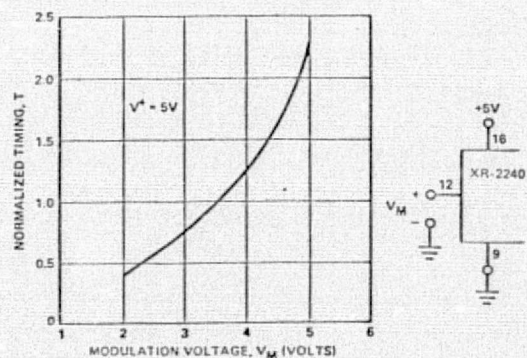


Figure 13. Normalized Change in Time-Base Period As a Function of Modulation Voltage at Pin 12

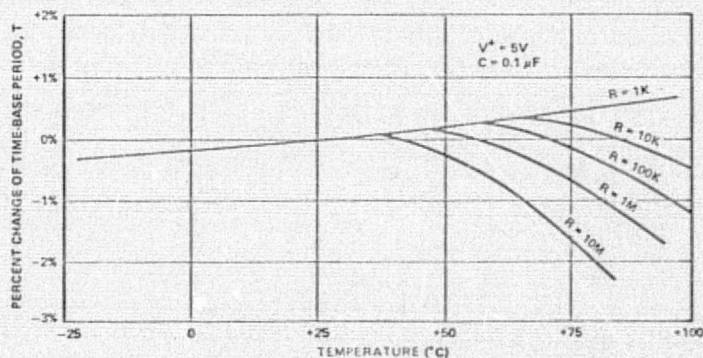


Figure 14. Temperature Drift of Time-Base Period, T

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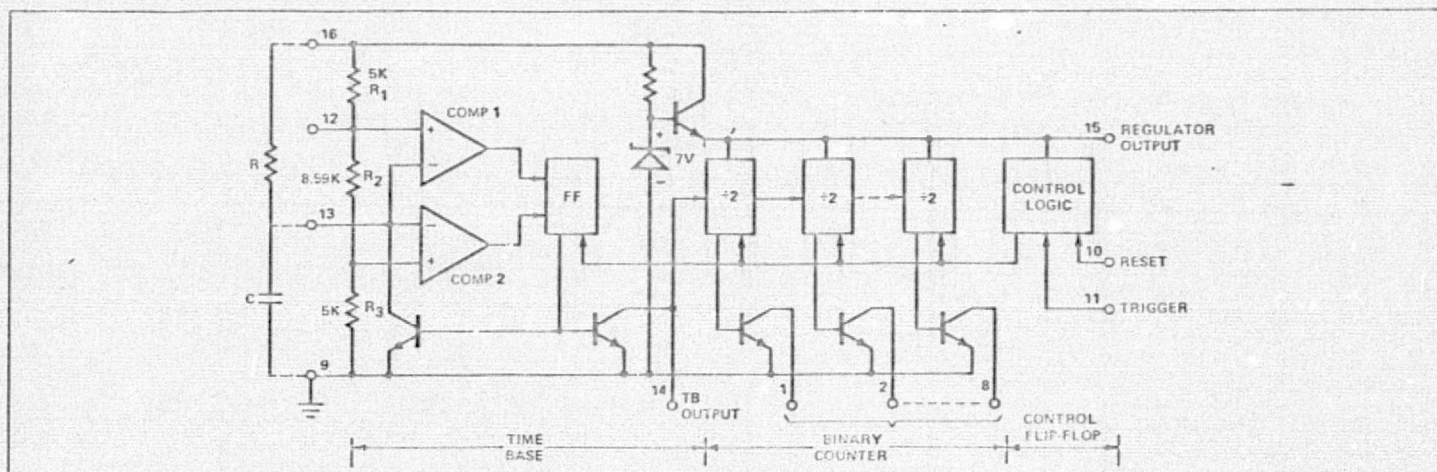


Figure 15. Simplified Circuit Diagram of XR-2240

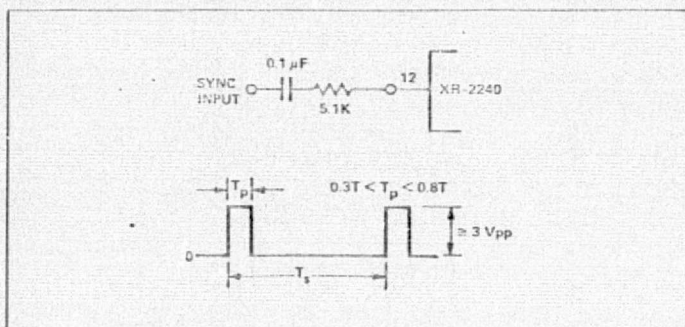


Figure 16. Operation with External Sync Signal.

- (a) Circuit for Sync Input
(b) Recommended Sync Waveform

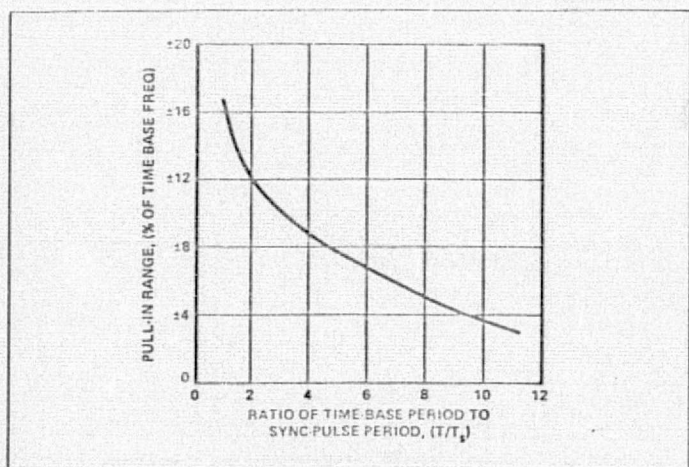


Figure 17. Typical Pull-In Range for Harmonic Synchronization

TIMING TERMINAL (PIN 13)

The time-base period T is determined by the external R-C network connected to this pin. When the time-base is triggered, the waveform at pin 13 is an exponential ramp with a period $T = 1.0 RC$.

TIME-BASE OUTPUT (PIN 14)

Time-Base output is an open-collector type stage, as shown in Figure 15 and requires a $20 K\Omega$ pull-up resistor to Pin 15 for proper operation of the circuit. At reset state, the time-base output is at "high" state. Subsequent to triggering, it produces a negative-going pulse train with a period $T = RC$, as shown in the diagram of Figure 5.

Time-base output is internally connected to the binary counter section and also serves as the input for the external clock signal when the circuit is operated with an external time-base.

The counter input triggers on the negative-going edge of the timing or clock pulses applied to pin 14 (see Figure 11). The trigger threshold for the counter section is $\approx +1.5$ volts. The counter section can be disabled by clamping the voltage level at pin 14 to ground.

REGULATOR OUTPUT (PIN 15)

This terminal can serve as a V^+ supply to additional XR-2240 circuits when several timer circuits are cascaded (See Figure 20), to minimize power dissipation. For circuit operation with external clock, pin 15 can be used as the V^+ terminal to power-down the internal time-base and reduce power dissipation.

When the internal time-base is used with $V^+ \leq 4.5V$, pin 15 should be shorted to pin 16.

APPLICATIONS INFORMATION

PRECISION TIMING (Monostable Operation)

In precision timing applications, the XR-2240 is used in its monostable or "self-resetting" mode. The generalized circuit connection for this application is shown in Figure 18.

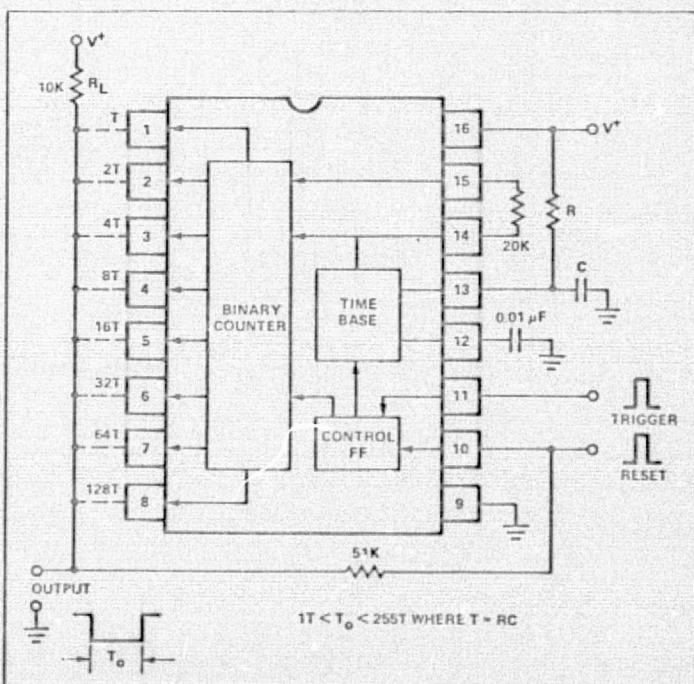


Figure 18. Circuit for Monostable Operation ($T_0 = NRC$ where $1 \leq N \leq 255$)

The output is normally "high" and goes to "low" subsequent to a trigger input. It stays low for the time duration T_O and then returns to the high state. The duration of the timing cycle T_O is given as:

$$T_O = NT = NRC$$

where $T = RC$ is the time-base period as set by the choice of timing components at pin 13 (See Figure 9). N is an integer in the range of:

$$1 \leq N \leq 255$$

as determined by the combination of counter outputs (pins 1 through 8) connected to the output bus, as described below.

PROGRAMMING OF COUNTER OUTPUTS: The binary counter outputs (pins 1 through 8) are open-collector type stages and can be shorted together to a common pull-up resistor to form a "wired-or" connection where the combined output will be "low" as long as any one of the outputs is low. In this manner, the time delays associated with each counter output can be summed by simply shorting them together to a common output bus as shown in Figure 18. For example, if only pin 6 is connected to the output and the rest left open, the total duration of the timing cycle, T_O , would be $32T$. Similarly, if pins 1, 5, and 6 were shorted to the output bus, the total time delay would be $T_O = (1+16+32)T = 49T$. In this manner, by proper choice of counter terminals connected to the output bus, one can program the timing cycle to be: $1T \leq T_O \leq 255T$.

ULTRA-LONG DELAY GENERATION

Two XR-2240 units can be cascaded as shown in Figure 19 to generate extremely long time delays. In this application, the reset and the trigger terminals of both units are tied together and the time base of Unit 2 disabled. In this manner, the output would normally be high when the system is at reset. Upon application of a trigger input, the output would go to a low state and stay that way for a total of $(256)^2$ or 65,536 cycles of the time-base oscillator.

PROGRAMMING: Total timing cycle of two cascaded units can be programmed from $T_O = 256RC$ to $T_O = 65,536RC$ in 256 discrete steps by selectively shorting any one or the combination of the counter outputs from Unit 2 to the output bus.

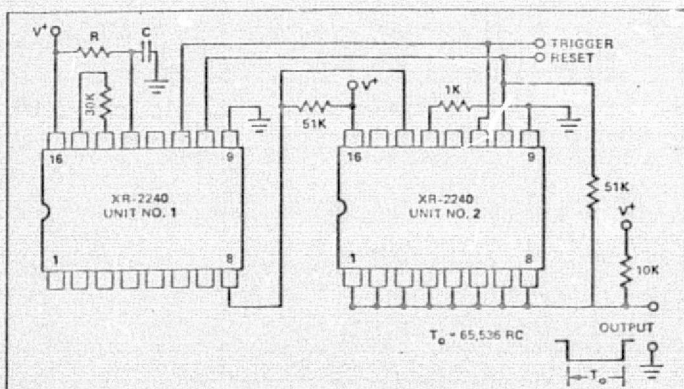


Figure 19. Cascaded Operation for Long Delay Generation

LOW-POWER OPERATION

In cascaded operation, the time-base section of Unit 2 can be powered down to reduce power consumption, by using the circuit connection of Figure 20. In this case, the V^+ terminal (pin 16) of Unit 2 is left open-circuited, and the second unit is powered from the regulator output of Unit 1, by connecting pin 15 of both units.

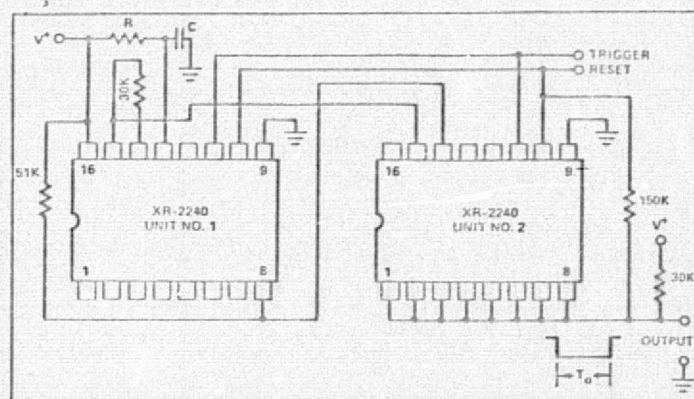


Figure 20. Low-Power Operation of Cascaded Timers

ASTABLE OPERATION

The XR-2240 can be operated in its astable or free-running mode by disconnecting the reset terminal (pin 10) from the counter outputs. Two typical circuit connections for this mode of operation are shown in Figure 21. In the circuit connection of Figure 21(a), the circuit operates in its free-running mode, with external trigger and reset signals. It will start counting and timing subsequent to a trigger input until an external reset pulse is applied. Upon application of a positive-going reset signal to pin 10, the circuit reverts back to its rest state. The circuit of Figure 21(a) is essentially the same as that of Figure 6, with the feedback switch S_1 open.

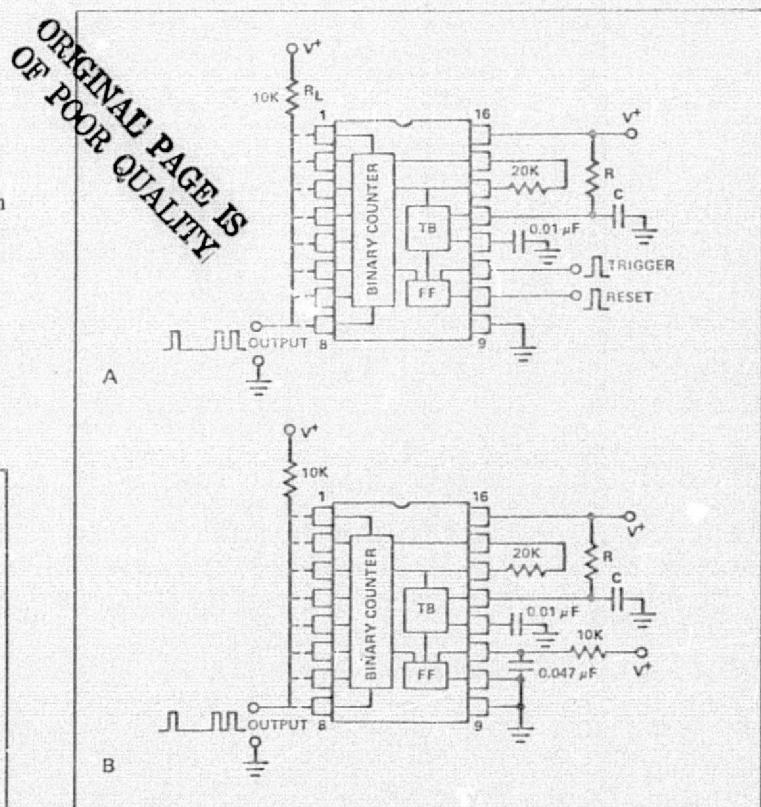


Figure 21. Circuit Connections for Astable Operation
(a) Operation with External Trigger and Reset Controls
(b) Free-running or Continuous Operation

The circuit of Figure 21(b) is designed for continuous operation. The circuit self-triggers automatically when the power supply is turned on, and continues to operate in its free-running mode indefinitely.

In astable or free-running operation, each of the counter outputs can be used individually as synchronized oscillators; or they can be interconnected to generate complex pulse patterns.

BINARY PATTERN GENERATION

In astable operation, as shown in Figure 21, the output of the XR-2240 appears as a complex pulse pattern. The waveform of the output pulse train can be determined directly from the timing diagram of Figure 5 which shows the phase relations between the counter outputs. Figure 22 shows some of these complex pulse patterns. The pulse pattern repeats itself at a rate equal to the period of the *highest* counter bit connected to the common output bus. The minimum pulse width contained in the pulse train is determined by the *lowest* counter bit connected to the output.

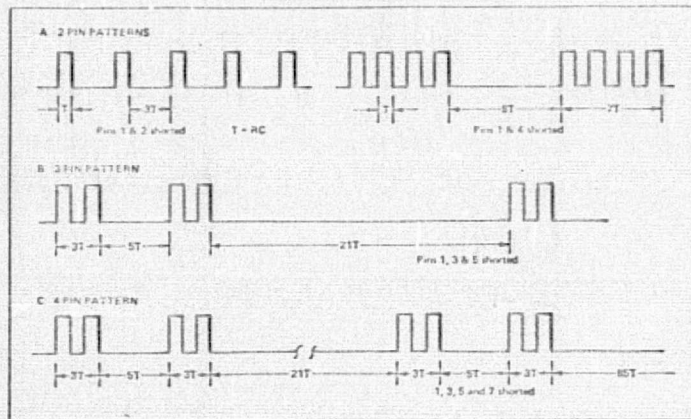


Figure 22. Binary Pulse Patterns Obtained by Shorting Various Counter Outputs

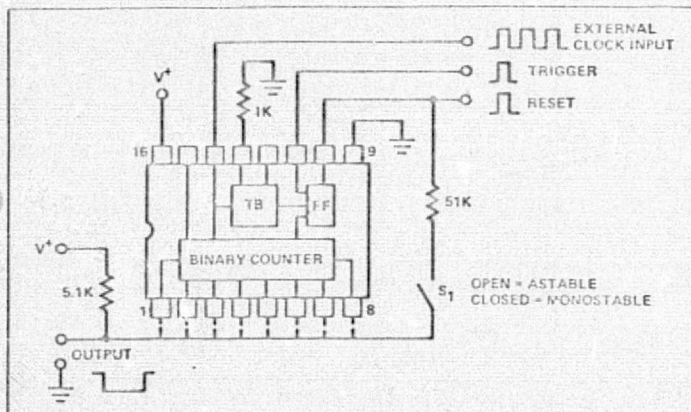


Figure 23. Operation with External Clock

OPERATION WITH EXTERNAL CLOCK

The XR-2240 can be operated with an external clock or time-base, by disabling the internal time-base oscillator and applying the external clock input to pin 14. The recommended circuit connection for this application is shown in Figure 23. The internal time-base can be de-activated by connecting a 1 KΩ resistor from pin 13 to ground. The counters are triggered on the negative-going edges of the external clock pulse. For proper operation, a minimum clock pulse amplitude of 3 volts is required. Minimum external clock pulse widths are shown in Figure 11.

For operation with supply voltages of 6V or less, the internal time-base section can be powered down by open-circuiting pin 16 and connecting pin 15 to V+. In this configuration, the internal time-base does not draw any current, and the over-all current drain is reduced by ≈3 mA.

FREQUENCY SYNTHESIZER

The programmable counter section of XR-2240 can be used to generate 255 discrete frequencies from a given time base setting using the circuit connection of Figure 24. The output of the circuit is a positive pulse train with a pulse width equal to T, and a period equal to (N+1) T where N is the programmed count in the counter.

The modulus N is the *total count* corresponding to the counter outputs connected to the output bus. Thus, for example, if pins 1, 3 and 4 are connected together to the output bus, the total count is: $N=1+4+8=13$; and the period of the output waveform is equal to (N+1) T or 14T. In this manner, 256 different frequencies can be synthesized from a given time-base setting.

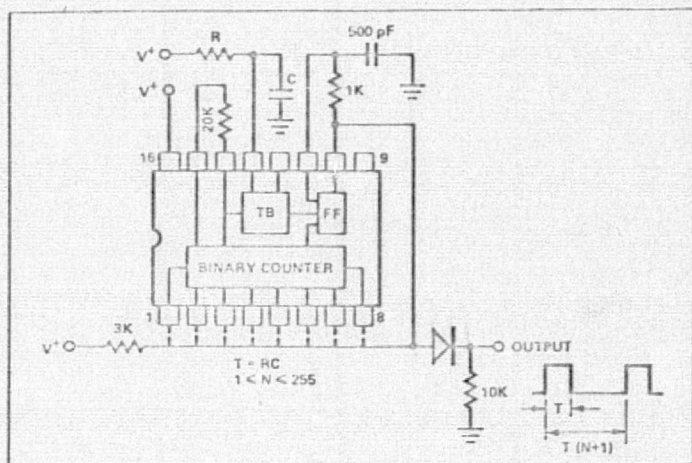


Figure 24. Frequency Synthesis from Internal Time-Base

SYNTHESIS WITH HARMONIC LOCKING: The harmonic synchronization property of the XR-2240 time-base can be used to generate a wide number of discrete frequencies from a given input reference frequency. The circuit connection for this application is shown in Figure 25. (See Figures 16 and 17 for external sync waveform and harmonic capture range.) If the time base is synchronized to (m)th harmonic of input frequency where $1 \leq m \leq 10$, as described in the section on "Harmonic Synchronization", the frequency f_0 of the output waveform in Figure 25 is related to the input reference frequency f_R as:

$$f_0 = f_R \frac{m}{(N+1)}$$

where m is the harmonic number, and N is the programmed counter modulus. For a range of $1 \leq N \leq 255$, the circuit of Figure 25 can produce 2550 different frequencies from a single fixed reference.

One particular application of the circuit of Figure 25 is generating frequencies which are not harmonically related to a reference input. For example, by choosing the external R-C to set $m = 10$ and setting $N = 5$, one can obtain a 100 Hz output frequency synchronized to 60 Hz power line frequency.

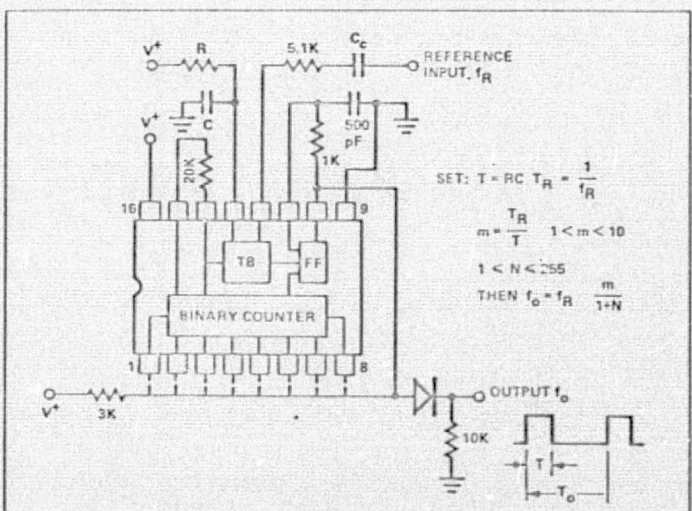


Figure 25. Frequency Synthesis by Harmonic Locking to an External Reference

STAIRCASE GENERATOR

The XR-2240 Timer/Counter can be interconnected with an external operational amplifier and a precision resistor ladder to form a staircase generator, as shown in Figure 26. Under reset condition, the output is low. When a trigger is applied, the op. amp. output goes to a high state and generates a negative going staircase of 256 equal steps. The time duration of each step is equal to the time-base period T . The staircase can be stopped at any desired level by applying a "disable" signal to pin 14, through a steering diode, as shown in Figure 26. The count is stopped when pin 14 is clamped at a voltage level less than 1.4V.

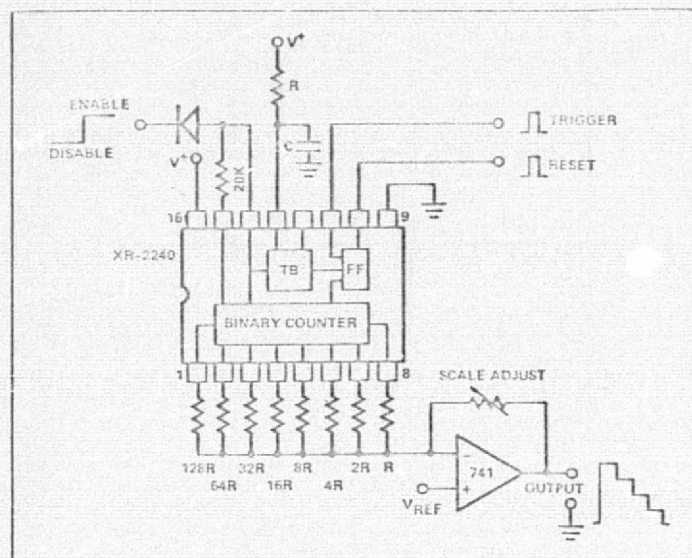


Figure 26. Staircase Generator

DIGITAL SAMPLE/HOLD

Figure 27 shows a digital sample and hold circuit using the XR-2240. The principle of operation of the circuit is similar to the staircase generator described in the previous section. When a "strobe" input is applied, the RC low-pass network between the reset and the trigger inputs of XR-2240 causes the timer to be first reset and then triggered by the same strobe input. This strobe input also sets the output of the bistable latch to a high state and activates the counter.

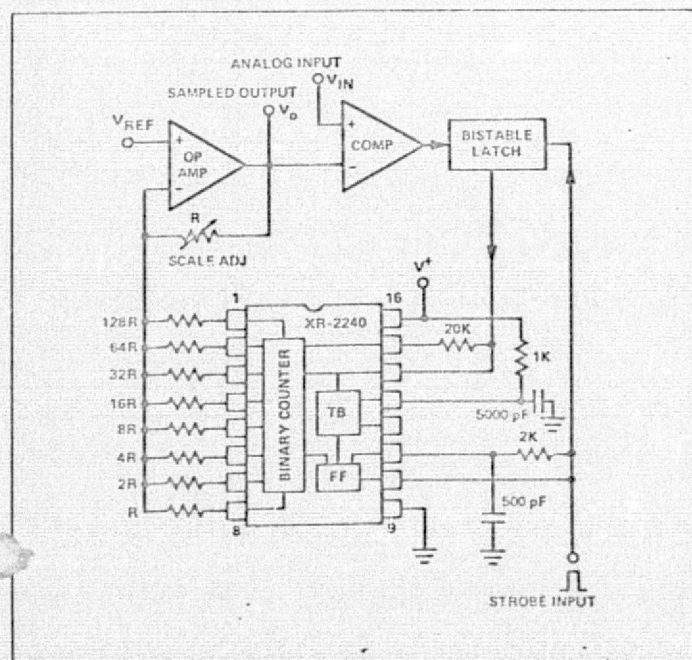


Figure 27. Digital Sample and Hold Circuit

The circuit generates a staircase voltage at the output of the op. amp. When the level of the staircase reaches that of the analog input to be sampled, comparator changes state, activates the bistable latch and stops the count. At this point, the voltage level at the op. amp. output corresponds to the sampled analog input. Once the input is sampled, it will be held until the next strobe signal. Minimum re-cycle time of the system is ≈ 3 msec.

ANALOG-TO-DIGITAL CONVERTER

Figure 28 shows a simple 8-bit A/D converter system using the XR-2240. The operation of the circuit is very similar to that described in connection with the digital sample/hold system of Figure 15. In the case of A/D conversion, the digital output is obtained in parallel format from the binary counter outputs, with the output at pin 8 corresponding to the most significant bit (MSB). The re-cycle time of the A/D converter is ≈ 3 msec.

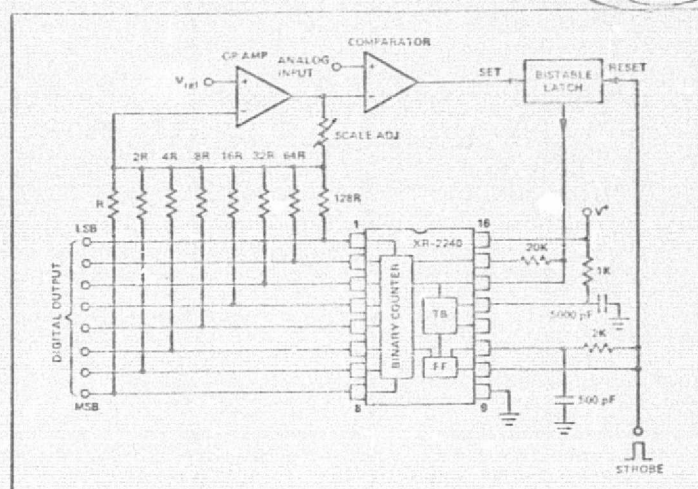


Figure 28. Analog-To-Digital Converter

ORDER INFORMATION

Part Number	Operating Temperature Range	Timing Error	Stability (0°C to +75°C)	Package
XR-2240MN	-55°C to +125°C	2% max	150 ppm/°C max	Ceramic
XR-2240N	0°C to +75°C	2% max	150 ppm/°C max	Ceramic
XR-2240P	0°C to +75°C	2% max	150 ppm/°C max	Plastic
XR-2340CN	0°C to +75°C	5% max	50 ppm/°C typ	Ceramic
XR-2340CP	0°C to +75°C	5% max	50 ppm/°C typ	Plastic

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Appendix XI

The following is a step by step procedure for the mechanical assembly of the Non-Spin Platform. All detail (DET.) are in reference to Drawing 95M16000, Non-Spin Platform - Assembly.

1. Press Seal (Det. 26) into (Det. 5), and (Det. 27) into (Det. 9).
2. Mount bearing (Det. 58) onto shaft against shoulder.
3. Mount (Det. 8) onto shaft and lock in place.
4. Mount seal (Det. 25) in position onto (Det. 8).
5. Slip signal slip ring (Det. 56) onto (Det. 8) routing wires left and right accordingly, and lock in place with ring.
6. Place shaft in vertical position with forward end down, and press hub over bearing and seal.
7. Press seal (Det. 25) into hub.
8. Assemble wave washers onto shaft.
9. Press bearing (Det. 58) into place.
10. Slip locking ring into place (Det 60) and torque (Det. 59) to pre-load bearings.
11. Mount (Det. 9).
12. Mount (Det. 5).
13. Slip torque motor rotor into magnetic ring and remove keeper.
14. Assemble (Det. 6) and magnetic ring of torque motor.
15. Mount brush blocks onto torque motor.

16. Mount torque motor assembly onto shaft and secure with (Det. 13).
17. Screw (Det. 11) onto shaft and mount end plate (Det. 4).
18. Mount power slip ring and route wires.
19. Screw (Det. 11) onto shaft and mount end plate (Det. 3).
20. Mount power brush block.
21. Assemble Details 87, 88, and 62.

The above does not include the mounting and wiring of many electrical components. The mounting and wiring of these components is, for the most part, straight forward. The physical location of the components are shown on 95M16000 and the wiring as defined by 95M16028, Figure 5.

Dis-assembly is accomplished in the reverse sequence of the assembly procedure.

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